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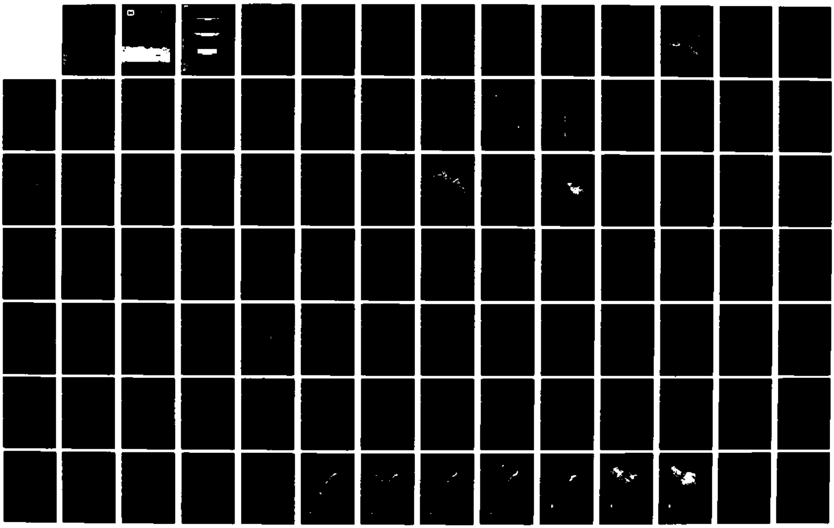

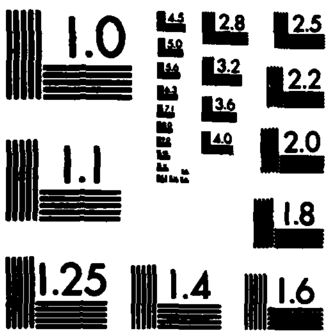

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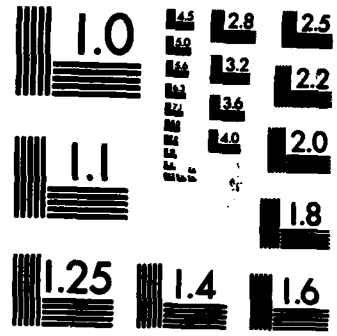

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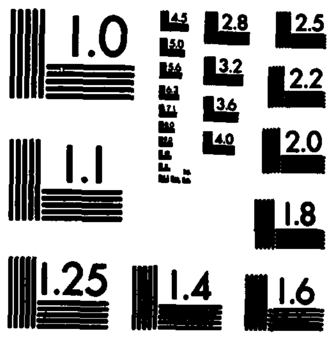

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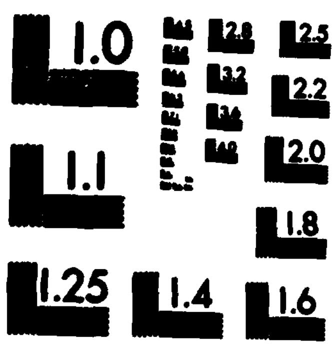

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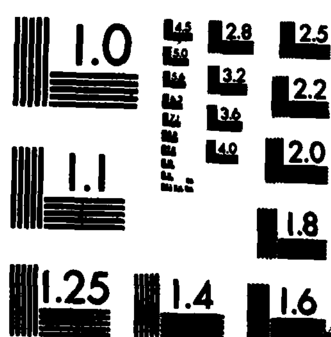

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TECHNICAL REPORT HL-82-15-3

THE ATCHAFALAYA RIVER DELTA

Report 3
EXTRAPOLATION OF DELTA GROWTH

by

Joseph V. Letter, Jr.

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

July 1982
Report 3 of a Series

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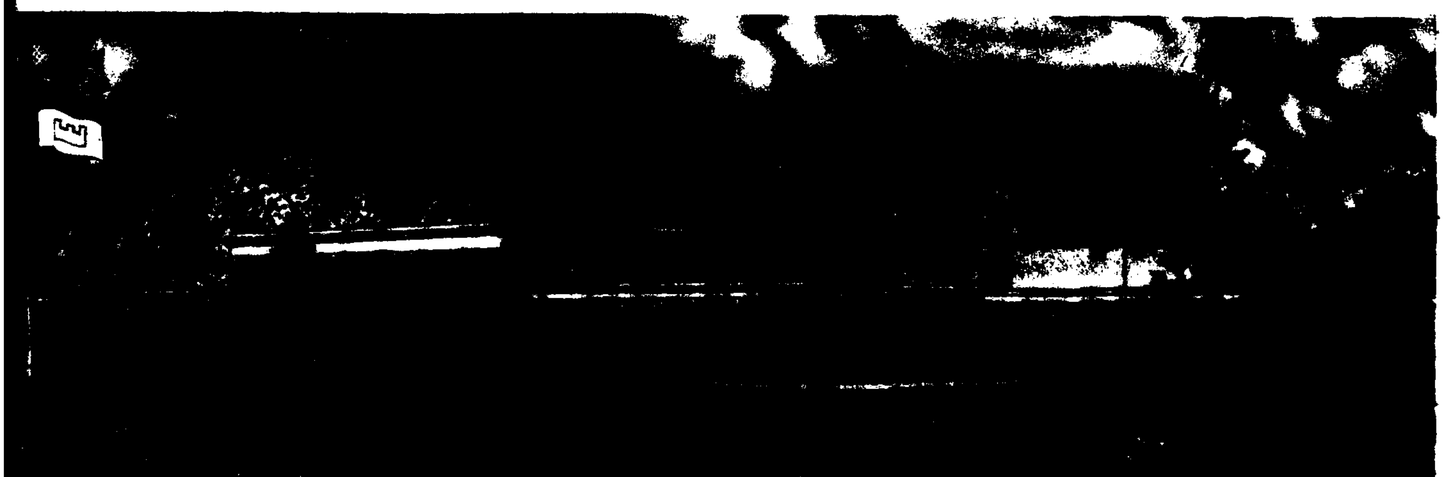

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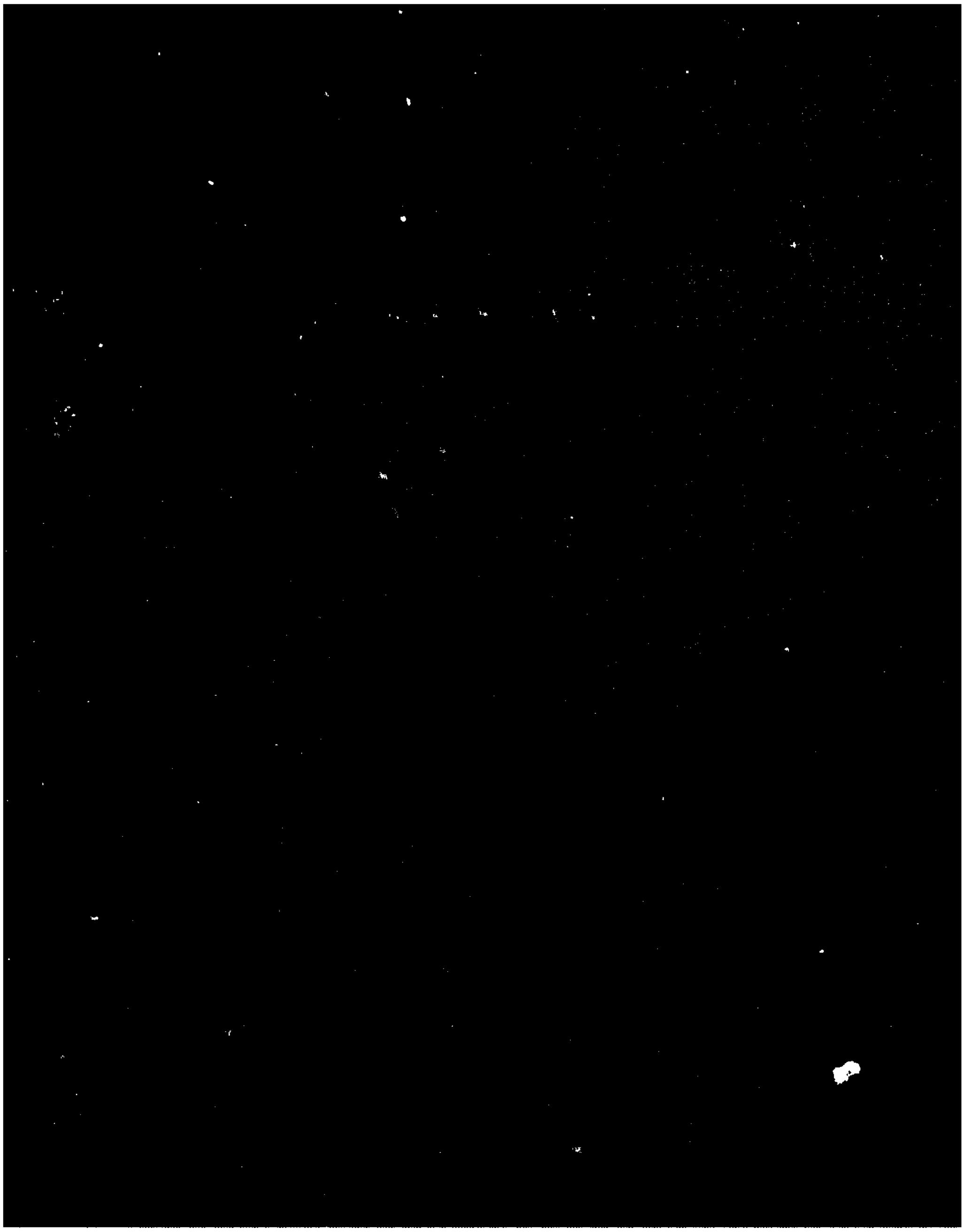

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study predicts the future delta growth of the Lower Atchafalaya River delta based on an extrapolation of historical deposition trends in Atchafalaya Bay. The prediction is made with a regression model developed by correlating deposition rates with river discharge, sediment yield, local water depth, and location relative to the delta mass centroid. The regression model is applied to a 50-yr hydrograph using the 1977 bathymetry as initial condition. The predicted delta condition at 10-yr increments is reported. Sensitivity tests

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20. ABSTRACT (Continued).

were made with the regression model which determined that the sequencing of hydrologic events had no impact on the resultant 50-yr condition, provided the total water and sediment entering the bay remained unchanged by resequencing events. It was concluded that within 50 yr the delta should evolve gulfward of Eugene Island, the gulfward limit of the bay.

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PREFACE

The work reported herein was performed in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) as a part of the overall investigation to predict the evolution of the Atchafalaya Bay delta. The study design (Phase I of the study) was authorized by the U. S. Army Engineer District, New Orleans (LMN), on 18 July 1977. Mr. W. H. McAnally, Jr., and Mr. S. B. Heltzel guided a team of personnel in the development of the plan. The implementation of the study plan (Phase II) was authorized by LMN on 21 May 1979. This report presents the first milestone of Phase II, the analytical extrapolation of the delta evolution based on historical data.

This work was performed under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, Mr. F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory, Mr. R. A. Sager, Chief of the Estuaries Division, and Mr. G. M. Fisackerly, previously Chief of the Harbor Entrance Branch. The work was performed by Mr. J. V. Letter, Jr., with the assistance of Mr. R. Schneider and Mr. D. Stewart. Gratitude is extended to Mrs. B. P. Donnell and Mr. W. H. McAnally for consultation. Consultants to the project were Mr. L. R. Beard, Dr. C. R. Kolb, Dr. R. B. Krone, and Mr. F. B. Toffaletti (deceased).

Commanders and Directors of WES during this study and the preparation and publication of this report were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
cubic feet per second	0.02831685	cubic metres per second
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (U. S. statute)	2.589988	square kilometres
tons (2,000 lb, mass)	907.1847	kilograms

THE ATCHAFALAYA RIVER DELTA

EXTRAPOLATION OF DELTA GROWTH

PART I: INTRODUCTION

Background

1. The Atchafalaya River captures about 30 percent of the latitude flow (combined flow of the Mississippi River and Red River at the latitude of 31 deg north) at the Old River Diversion Structure (Figure 1), and carries with it an average of 94 million tons* of sediment (Keown, Dardeau, and Causey 1980) in suspension each year. This material has progressively filled in the Atchafalaya basin floodway between its natural levee systems over the past several decades and is now depositing rapidly in Atchafalaya Bay (Figure 2).

2. The evolving delta in Atchafalaya Bay is one of the most dynamic currently active deltas in the world. As the delta has evolved, converting shallow bay ecosystems into marsh ecosystems, a great deal of interest has been generated in deltaic processes in the bay and the impacts of man on this system.

3. The U. S. Army Engineer District, New Orleans (LMN), in response to this interest, held a symposium during 24-25 June 1976 with the goal of organizing a comprehensive plan for Atchafalaya Bay.

4. The research needs identified during that symposium were:

<u>a</u>. To determine the behavior of river sediment as it enters the saline bay environment by use of mathematical modeling or analogy with prototype deltas.

<u>b</u>. To predict the impact of various policies of dredged material placement on channel efficiency, on optimal marsh building, and on the interaction of the deltas of the Lower Atchafalaya River and Wax Lake Outlet.

<u>c</u>. To identify the effects of various flow distributions between Lower Atchafalaya River and Wax Lake Outlet.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

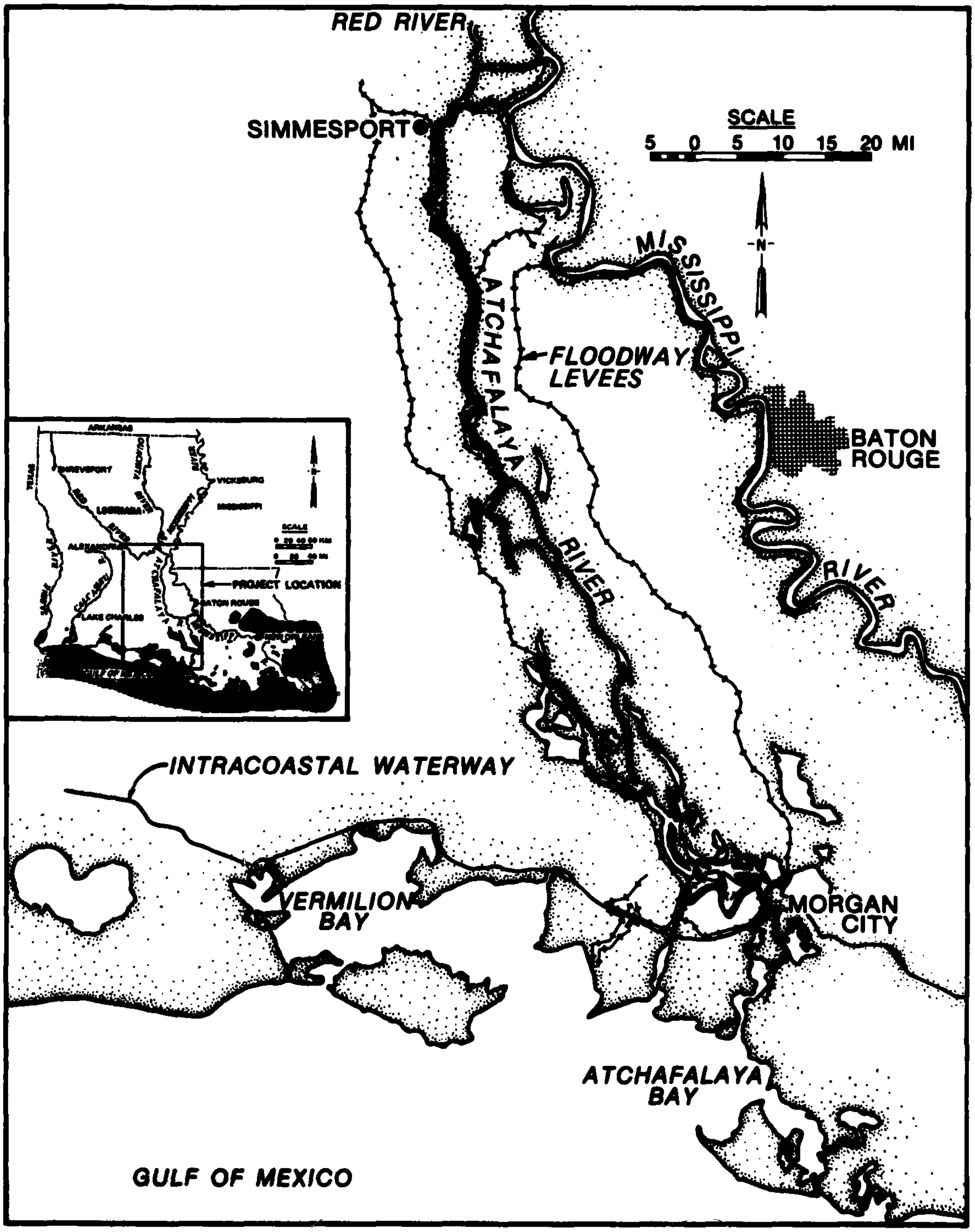

Figure 1. Project location

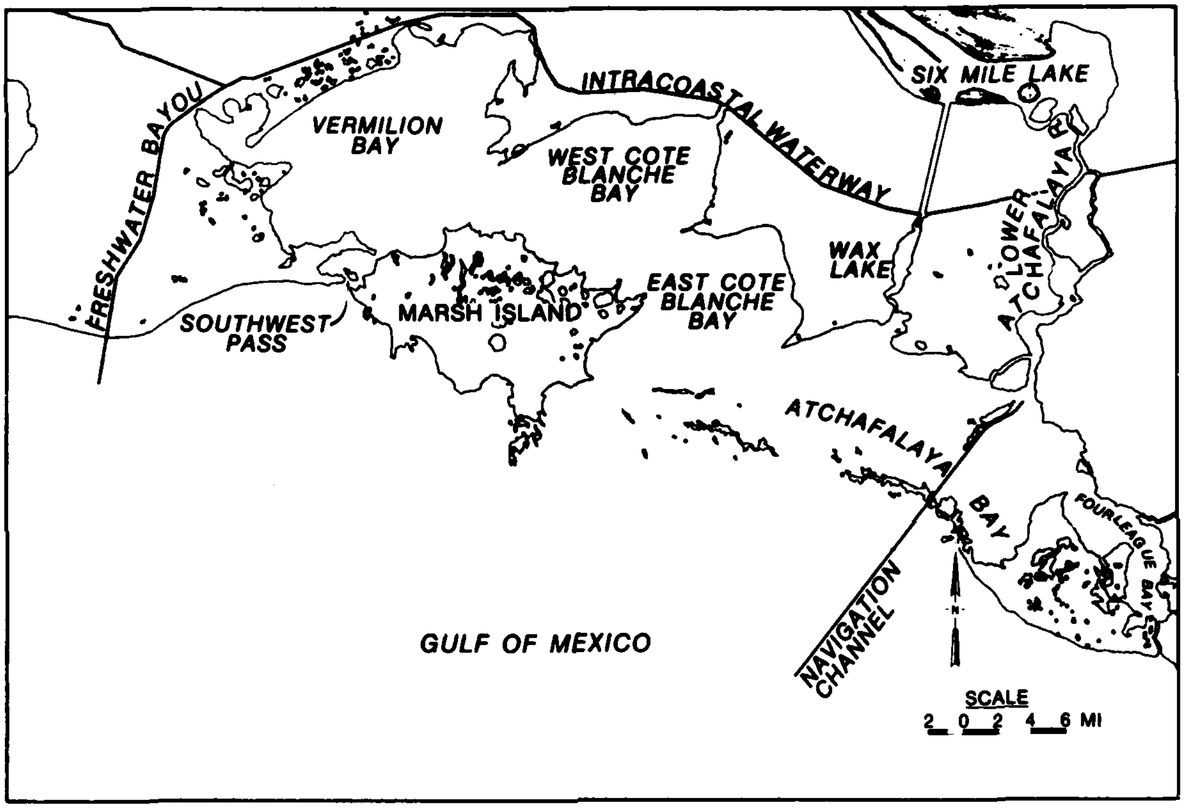

Figure 2. Location map of the Atchafalaya Bay area

d. To develop a mathematical model for bays and sounds to model sediment transport, circulation patterns, sediment-saltwater interactions, and water quality.

5. The U. S. Army Engineer Waterways Experiment Station (WES), at the request of LMN, proposed a plan of action aimed at the above research needs. The proposed approach is comprised of three phases:

a. Phase I: Plan development

b. Phase II: Plan implementation

c. Phase III: Monitoring

6. The development phase was to review available prototype data and plan a supplemental data collection program, if necessary. Then, based on the existing knowledge of the bay and phenomena of importance, the models were to be designed and the solution methods identified.

7. The implementation phase would involve collection of supplemental data, construction of the physical models, adoption of numerical models, and verification of all models. These tools were to be applied to determine the effects of various stages of bay development, defining the system characteristics, potential problems, and possible solutions.

8. The monitoring phase would include both field data collection to monitor development and model tests to update predictions based on recent prototype experience and advances in model technology. As new problems develop, solutions and their impact could be generated.

9. The WES proposal was approved 2 June 1977 by the Office, Chief of Engineers (OCE), and work began on Phase I on 1 September 1977. Results of Phase I were presented to LMN in an unpublished document (McAnally and Heltzel 1978), "A Plan for Predicting the Evolution of Atchafalaya Bay, Louisiana."

10. The plan utilizes multiple levels of sophistication in addressing the delta evolution in Atchafalaya Bay. Figure 3 presents the philosophy of the plan. The simplest approach is to extrapolate observed behavior into the future. Increasing the level of effort, a simple quasi two-dimensional numerical model would be expected to more adequately handle the problem. For even more capability, a two-dimensional numerical modeling approach will allow dynamic testing of tidal effects, storm

OPERATIONS TO PREDICT SEDIMENT TRANSPORT AND GROWTH OF THE DELTA

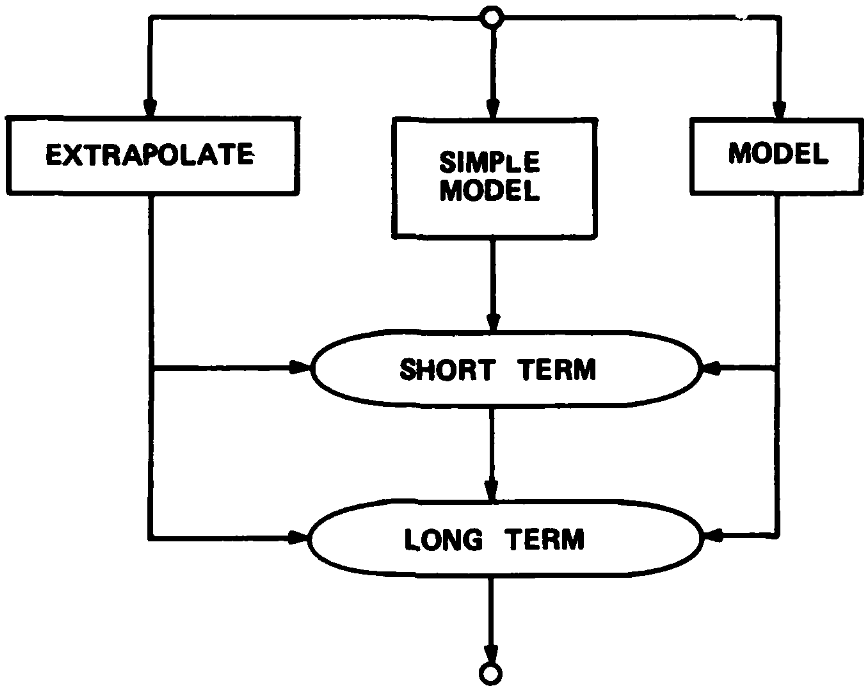

Figure 3. Philosophy of overall plan for predicting the delta evolution in Atchafalaya Bay

surges, winds and waves, and other complex phenomena.

11. The work reported herein is the first level of complexity in predicting evolution of the delta in Atchafalaya Bay. It consists of the simple extrapolation of observed delta formation into the future. This represents the first milestone of Phase II of the project.

Objective

12. The objective of the overall project is to develop a set of tools to predict the evolution of the Atchafalaya River delta and the effects of that evolution. One of those tools that has been developed is the extrapolation method reported herein.

13. The objectives of the extrapolation task are:

a. Primary objective. To predict the evolution of the delta within Atchafalaya Bay over both the short and long term.

b. Secondary objectives.

(1) To utilize a sound statistical basis for the projections.

(2) To make the approach simple to apply so that the predictions may be updated when new field data become available.

(3) To keep the overall approach flexible so new knowledge of deltaic processes can easily be included in revising predictions.

(4) To design the extrapolation technique to address the variability of the hydrologic regime entering the system.

Approach

14. The plan of attack in this task was designed to be flexible, portable, and simple. Figure 4 illustrates the major steps in this task. The data base is the common factor in each step of the analysis. The value of any scientific work can be in part measured by the accuracy of data used in the analysis. Therefore, considerable effort was expended in compiling and checking the quality of the prototype data used in the analysis. Because of this level of effort in data handling, the WES System A (LaGarde and Heltzel 1980) data management system (DMS) was utilized.

15. Regression work was performed using the Statistical Package for Social Sciences (SPSS) system on the WES G635 computer. This statistical package is a common feature on many large computing systems, and therefore, some portability of the method is assured. The regression incorporated those parameters felt to be of significance to delta evolution. The regression model was applied to the historical data to confirm its ability to extend an initial condition forward in time with reasonable success. Extrapolation was performed using the regression model and a time series of parameters associated with a 50-yr hydrograph. A series of tests were then made to check the sensitivity of the method to changes in the extrapolation hydrograph and associated time series.

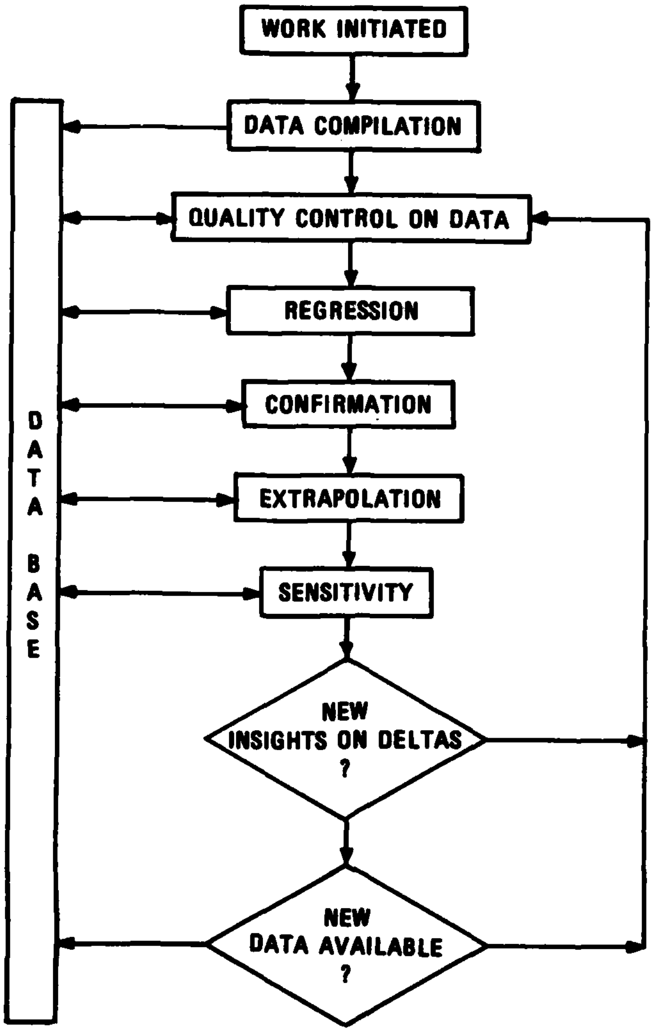

Figure 4. Approach for extrapolation study

16. The approach taken for this task, by addressing the goals set forth in paragraph 13 above, is designed to provide an end product that is reasonably easy to reapply and refine in the future as deemed necessary.

PART II: ATCHAFALAYA BAY SYSTEM

General Description

17. Atchafalaya Bay is located in the center of the Louisiana gulf coast (Figure 1) in the Teche delta, approximately 120 miles west of the modern Mississippi River delta. The bay is about 33 miles wide and 8 miles long, with a surface area of 233 square miles prior to recent rapid subaerial delta development. As of 1980, approximately 26 square miles of subaerial delta had been recently created in the bay.

18. Atchafalaya Bay is very shallow, with an average depth of about 5 ft below National Geodetic Vertical Datum (NGVD), 1929 adjustment (previously called mean sea level). On its western end, the bay blends into East Cote Blanche Bay via a wide (5 miles) opening near Point Chevreuil. On the eastern end of the bay, a passage about 1.5 miles wide leads to Four League Bay. The gulf side of the bay is bounded by a natural shell reef barrier which dissipates much of the wave energy incoming from the gulf. The subaerial extent of the reef is much less than existed 20 years ago, based on personal observations of individuals who have visited the reef over this period. Currently, water depths over the reef vary between 1 to 6 ft except for outcrops at Eugene Island. During some winter frontal passages and subsequent setdowns of water-surface elevations in the bay, other parts of the reef sometimes become exposed.

19. On the northern and eastern sides of the bay are low-lying marshes (2 to 3 ft above NGVD). The two principal sources of fresh water to the system, flowing through these marshes on the northern side of the bay, are Wax Lake Outlet and Lower Atchafalaya River.

Federal Projects

20. The Federal navigation channel in the Lower Atchafalaya River was originally authorized by the River and Harbor Act of 25 June 1910 to provide a 20- by 200-ft channel from the -20 ft contour in the bay to the

gulf -20 ft contour. That channel was completed in October 1911. The River and Harbor Act of 13 August 1968 further authorized the channel to its present 20- by 400-ft dimensions. This channel extends from the river mouth, through the Point au Fer shell reef near Eugene Island, and then to the -20 ft contour in the Gulf of Mexico.

21. Wax Lake Outlet and its floodway channel, 45 by 300 ft at its head in Six Mile Lake increasing to 45 by 400 ft at its mouth in Atchafalaya Bay, were authorized by the River and Harbor Act of 28 June 1938. The outlet was designed to provide an additional path to the bay for floodwaters and was completed in 1941.

22. Maintenance dredging requirements for the navigation channel between Morgan City and the gulf are presented in Table 1 and plotted in Figure 5. Notice that there was virtually no dredging during the period of 1919 through 1947, when the controlling depth in the navigation channel was allowed to drop to about 6 ft. During the project history (1910 to 1975), the controlling depth was greater than 10 ft only about 23 percent of the time. The average annual dredging for those years when maintenance was attempted was 1,600,000 cu yd of material. During the 2-year period from 15 May 1973 to 30 June 1975 (major flood periods), approximately 9.4 million cu yd of material were dredged from the navigation channel.

Energy Sources

23. There are several sources of significant energy for creating and reworking delta deposits in Atchafalaya Bay and vicinity.

Riverflows

24. The primary source of energy relative to delta evolution is the river discharge. The mean flow at Simmesport for the period 1938-1977 was 192,000 cfs. For the period of 1961-1977 the average flow was 212,000 cfs, while for 1972-1977 the average was 272,000 cfs, showing the impact of the high flood years 1973-1975. Figure 6 presents the variation in mean monthly discharges (Cratsley 1975) during the period July 1963 to July 1969. The maximum average monthly discharge of 325,000 cfs occurs in April, and the minimum monthly average of 73,000 cfs falls in September.

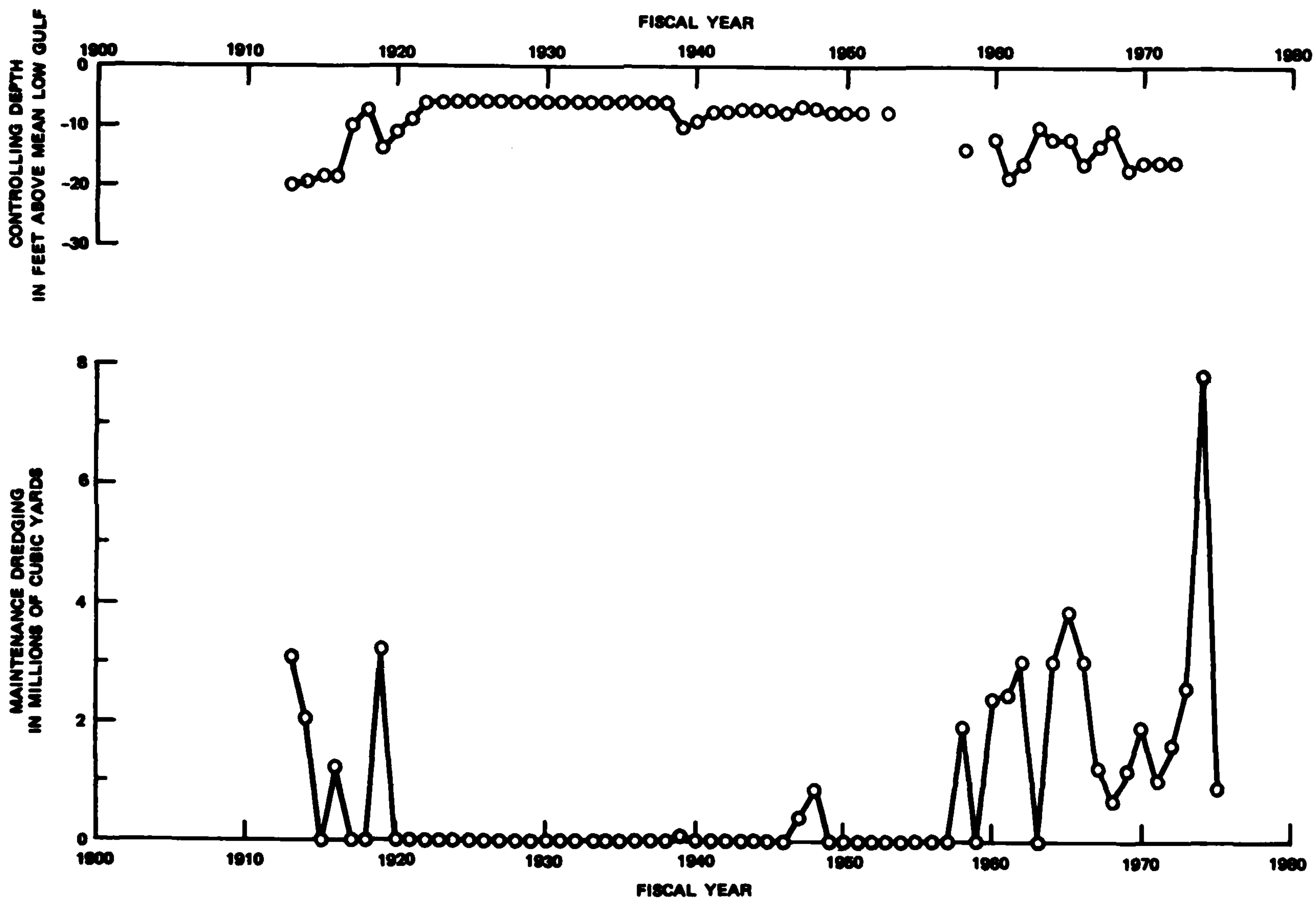

Figure 5. Maintenance dredging history of Lower Atchafalaya River

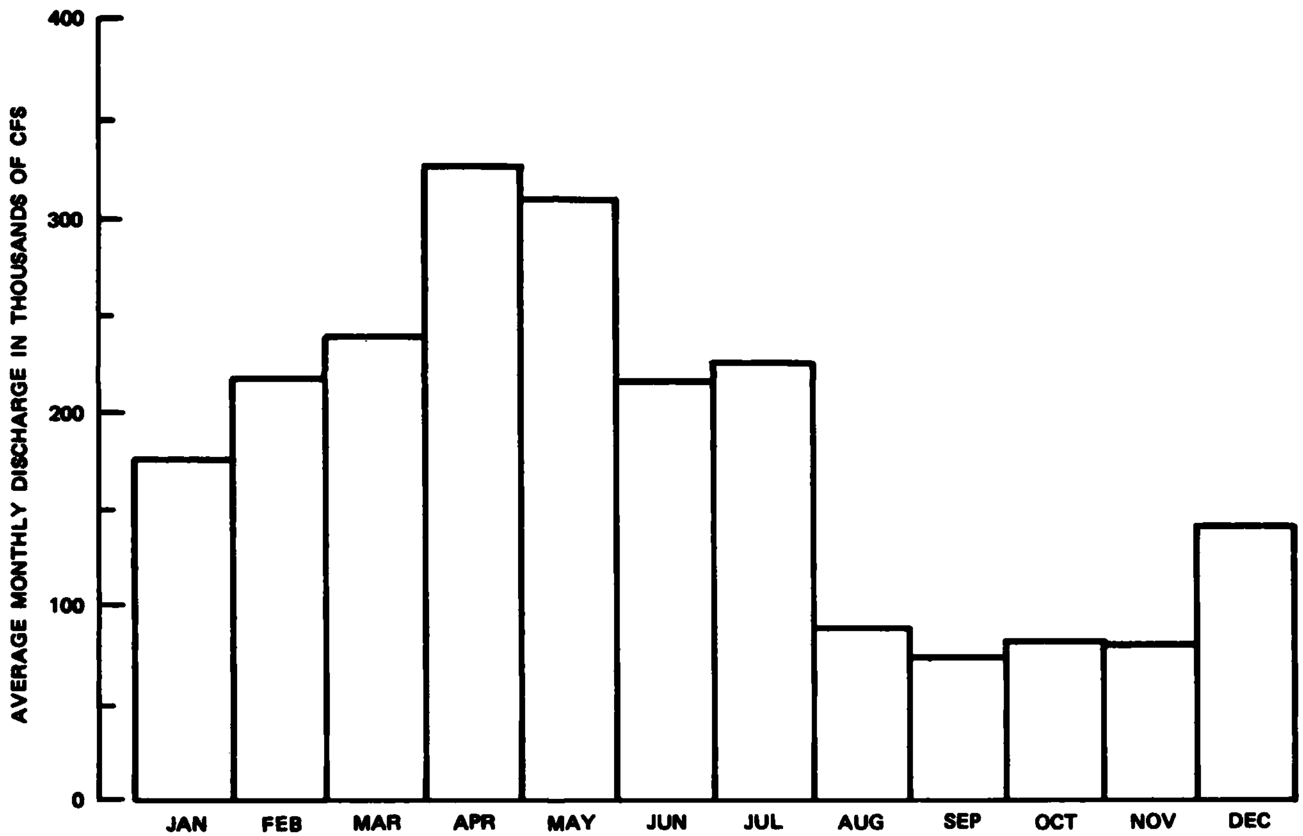

Figure 6. Average monthly discharge of the Lower Atchafalaya River for the period July 1963 to July 1969 (from Cratsley 1975)

25. The flow at the lower end of the basin is split between Wax Lake Outlet and the Lower Atchafalaya River by approximately 30 and 70 percent, respectively. During extremely high floods, as in 1973, the Morganza Floodway is opened, diverting additional Mississippi River flows into the Atchafalaya basin. Of the design flood of 3,030,000-cfs latitude flow at Old River, the Morganza structure would pass 600,000 cfs, 930,000 cfs would pass Simmesport, while a total of 1,500,000 cfs would be routed to the gulf through the Atchafalaya, with 30,000 cfs going to floodplain storage within the basin between Simmesport and Morgan City, and the remaining 1,500,000 cfs would pass via the lower Mississippi River system (Figure 7).

26. The location of Wax Lake Outlet relative to Morgan City gives it a distinct gradient advantage to Atchafalaya Bay. The distance to Atchafalaya Bay from the head of Six Mile Lake via Wax Lake Outlet is 15 miles, whereas it is 30 miles via the full length of Six Mile Lake and then the Lower Atchafalaya River. Increased sedimentation at the mouth of the Lower Atchafalaya River has accentuated the gradient advantage, and the flow distribution between the two passages has been changing. The percentage of flow passing via Wax Lake Outlet for high flows has increased from 20 percent in 1963 to approximately 30 percent at the present. During low-flow periods the percentage of Wax Lake Outlet flow has increased to around 45 percent of the total flow. The channel cross section in Wax Lake Outlet has accordingly gradually increased from 27,000 sq ft in 1963 to 36,000 sq ft in 1975. This increased area continues to give further advantage to the Wax Lake route to the bay for future diversion of flow. This is an illustrative example of the driving mechanism in deltaic processes.

<u>Astronomical tides</u>

27. The tides in the region of Atchafalaya Bay alternate between diurnal and mixed, with the principal diurnal (K1 and O1) tides being dominant over the principal semidiurnal (M2 and S2) constituents. The tides exhibit mixed-tide behavior during neap tide periods and diurnal-tide behavior during spring tide periods (Figure 8). The tidal characteristics for the period 1942-1967 expressed in feet referred to

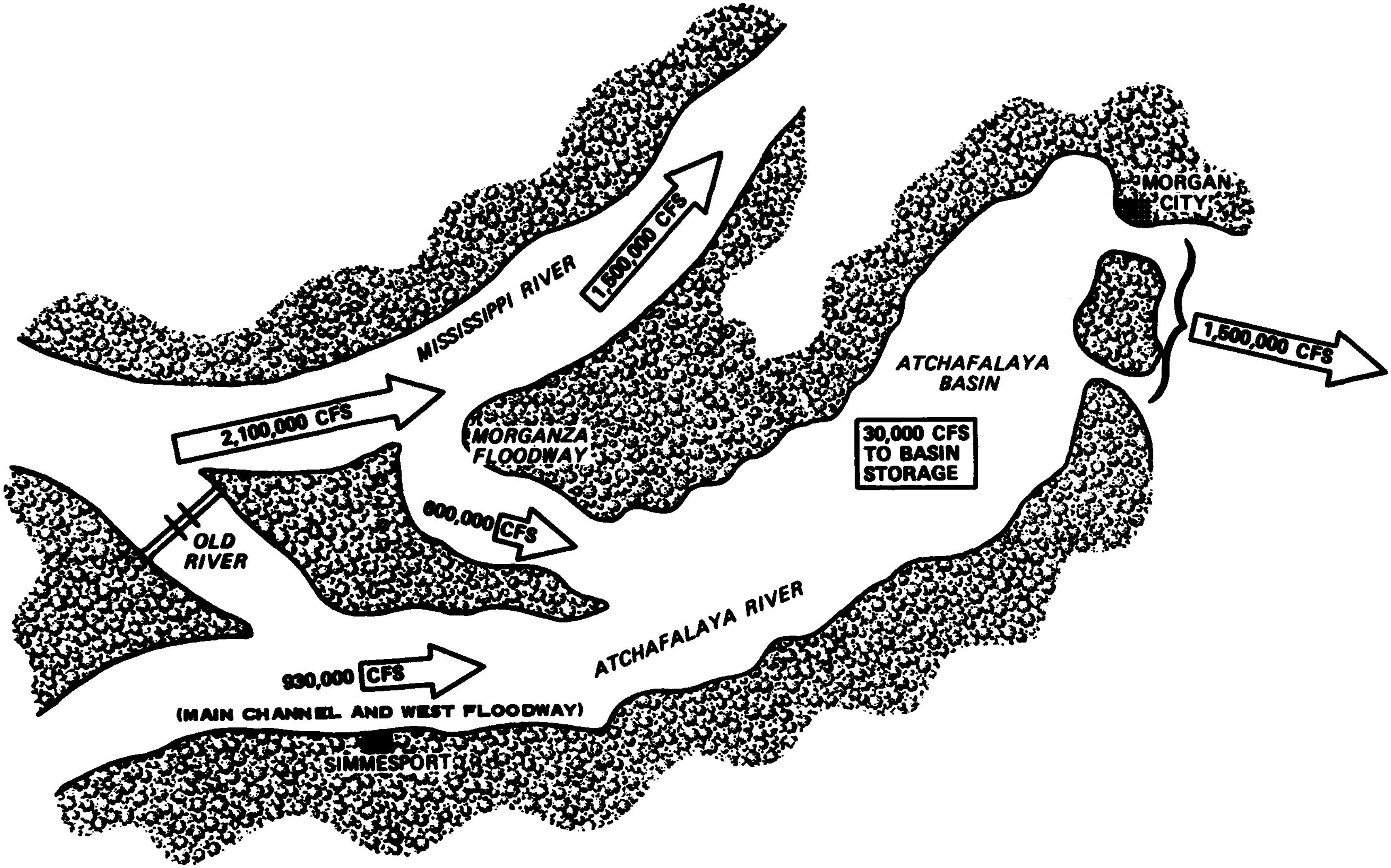

Figure 7. Routing of design flood through the Atchafalaya system

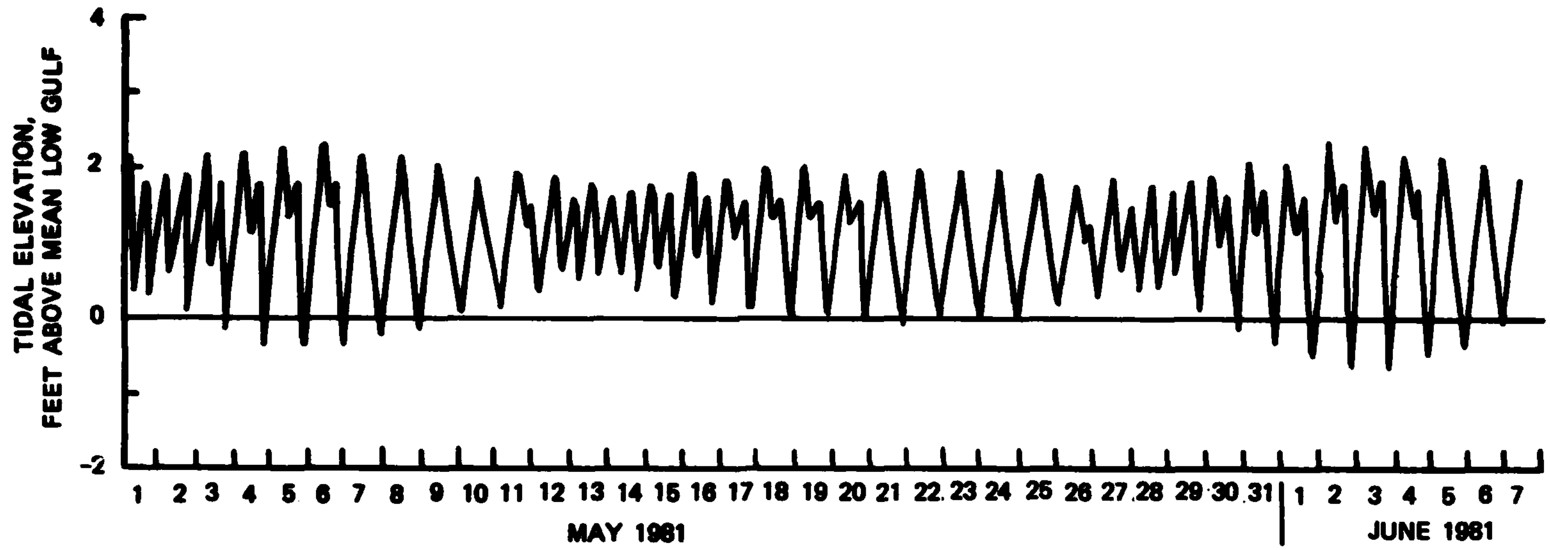

Figure 8. Typical tidal elevations at Eugene Island, La.

NGVD at Morgan City, Calumet, and Eugene Island are presented in Table 2.

28. The tidal energy is not of great significance relative to tidal energies on the Atlantic or Pacific coast; however, the circulation patterns induced in the bay by the tides may be important, since there is a predominant net transport of water to the west over the tidal cycle (Van Beek et al. 1977). The mean diurnal tidal range of 1.5 ft generates a tidal prism amounting to 25 percent of the volume of water within the bay. For a diurnal spring tide range of 2.7 ft the tidal prism is 40 percent of the bay volume. Although possibly less significant as energy for suspending sediments, tidal currents play an important role in transporting and flushing sediment suspended by other mechanisms.

Wave energy

29. The long east-west fetch length of Atchafalaya Bay results in wind-generated waves of 1 to 2 ft fairly frequently (Cratsley 1975). These waves provide the primary mechanism for resuspension of deltaic sediments on the delta lobes and are thought to be responsible for reworking of the delta during periods of prolonged low riverflow.

30. The barrier shell reef on the gulf side of the bay provides protection from gulf wave energy, but some energy is transmitted across the reef. Observations of waves from offshore oil platforms indicate that 95 percent of the time waves are less than 4 ft (Cratsley 1975). Waves as high as 10 ft have been observed during hurricanes. These high waves, coincident with surges in the water levels in the bay, provide a great deal of energy to the bay.

Storms

31. Plates 1-4 present the storm tracks of hurricanes and tropical storms in the Gulf of Mexico for the period 1950-1974. These storms are listed in Table 3. Plate 1 (1950-1955) shows only one tropical storm approaching the Atchafalaya Bay vicinity, but on a track that would generate waves at an oblique angle to the shoreline. The period 1956-1961 (Plate 2), however, shows two direct hits of tropical storms, two near-misses of tropical storms, and several hurricanes passing close by on

tracks favorable for wave generation and propagation toward the area of interest.

32. Two hurricanes hit the Louisiana coast during the 1962-1965 period (Plate 3).

33. The 1967-1974 period shows three storms that pass the area, only one of which had sufficient fetch and duration to generate substantial waves. One other passed offshore east of the bay in a manner that would have caused a substantial setdown in the bay.

34. Winter storm fronts that pass through the area can have a significant impact on the water-surface elevations in the bay (Van Heerden and Roberts 1980). Typically the fronts pass from the northwest to southeast, with winds shifting from a southwesterly direction to a northeasterly direction as the front passes. The southwesterly winds preceding the front passage cause a setup of water-surface elevations within the bay; then as the front passes, the northeasterly winds in addition to the gradient in water surface during setup push the water out of the bay and cause a setdown to water level that exposes much of the delta front to wave action. Tides 2 ft below normal are not uncommon after frontal passages (Van Heerden 1980).

Salinity

35. As is the case in almost all bays and estuaries, the salinity regime of the bay responds inversely to the hydrologic regime, with maximum salinities corresponding to times of minimum discharge and minimum salinities at times of maximum discharge. The severity of salinity extremes is related to the severity of the hydrologic extremes. The lowest salinities are found in the eastern portion of Atchafalaya Bay and the highest are found in the western portions of Vermilion Bay and in Southwest Pass and Freshwater Bayou channel, the regions most removed from the influence of the diluting Atchafalaya River waters. There is very little variation of salinity over depth for most portions of the bay with the exception of that in the navigation channel (Juneau and Barrett 1975).

Sediment Characteristics

36. The supply of sediments to Atchafalaya Bay has been changing over the past several decades, both in volume and character. The average annual suspended sediment load of the Lower Atchafalaya River for the period 1965-1971 was estimated to be 47 million tons (New Orleans District 1974). The average annual suspended sediment load during the high flow years of 1973-1975 was 98 million tons.

37. The character of the sediments entering Atchafalaya Bay has been dictated for quite some time by the sedimentation processes within the floodway. Prior to the mid-1950's, the sediment supply to the bay was restricted to a portion of fine-grained suspended sediments of the Atchafalaya River washing through the basin, which trapped most of the coarser grained material (Cratsley 1975). As the Atchafalaya floodway has gradually filled with sediment to the point where only a few principal channels carry the river's load of water and sediments, the basin trap efficiency has decreased. Accordingly, the size distribution of the material entering the bay has shifted from silts and clays toward fine sands, silts, and clays during the past 20 yr (McAnally and Heltzel 1978).

38. The observed shift in grain sizes over this period is partly the effect of basin sedimentation and partly the influence of the extremely high riverflows during the later years of the period. Table 4 presents the results of a suspended load budget performed by Roberts, Adams, and Cunningham (1980) for the Atchafalaya River for the periods 1967-1971 and 1973-1975. The earlier period, which had only moderate flood flows, averaged a suspended load of 87.2 million tons (22 percent sand and 78 percent silt/clay) per year while the later period, which had the extremely high floods, averaged 148.2 million tons per year (25 percent sand and 75 percent silt/clay). These figures show a slight increase in the percentage sand in suspension during the flood years. The distribution of the silt and clay fractions shows only a minor shift toward more retention in the basin during the flood years, presumably due to losses to the floodplain within the basin. The sand distribution,

however, is drastically different for the two periods. The low-flow period had 75 percent of the sand retained in the basin, while the high-flow years showed only 10 percent of the sand was trapped in the basin. This picture is consistent with the rapid evolution of sand lobes in the bay during the later period.

Historical Perspective

39. Even though awesome in size, the Atchafalaya Bay is a small part of the overall geomorphic stage within which the Mississippi River, Atchafalaya River, and several other distributaries have vied for their share of the freshwater discharge. The Mississippi delta system covers about two-thirds of the Louisiana shoreline (approximately 300 miles) and spans 6,000 yr of deltaic sedimentation.

40. The sequence of delta building on the Louisiana coast is the result of periodic diversions of the Mississippi River from older, less efficient channels to shorter routes to the gulf, with a greater hydraulic gradient. These diversions also take place on smaller scales (spatially and temporally) involving small distributaries and channels of the overall delta system. The smaller scale diversions may occur during a single flood event within a small subdelta, on a spatial scale of hundreds or thousands of feet, and over time scales of days or weeks. The larger scale diversions occur over spatial scales of tens or hundreds of miles and time scales of thousands of years. Figure 9 presents these large scale diversions (or delta systems) as determined by a number of investigators (Russell 1936; Kolb and Van Lopik 1958; Coleman and Gagliano 1964).

41. Each of these delta developments is governed by the interactions of three groups of processes:

- a. Freshwater and sediment supply from the river.
- b. Reworking of delta deposits by energy from waves, tides, and currents.
- c. Apparent subsidence due to shifting of the earth's crust, compaction of sediments, and variations in sea level.

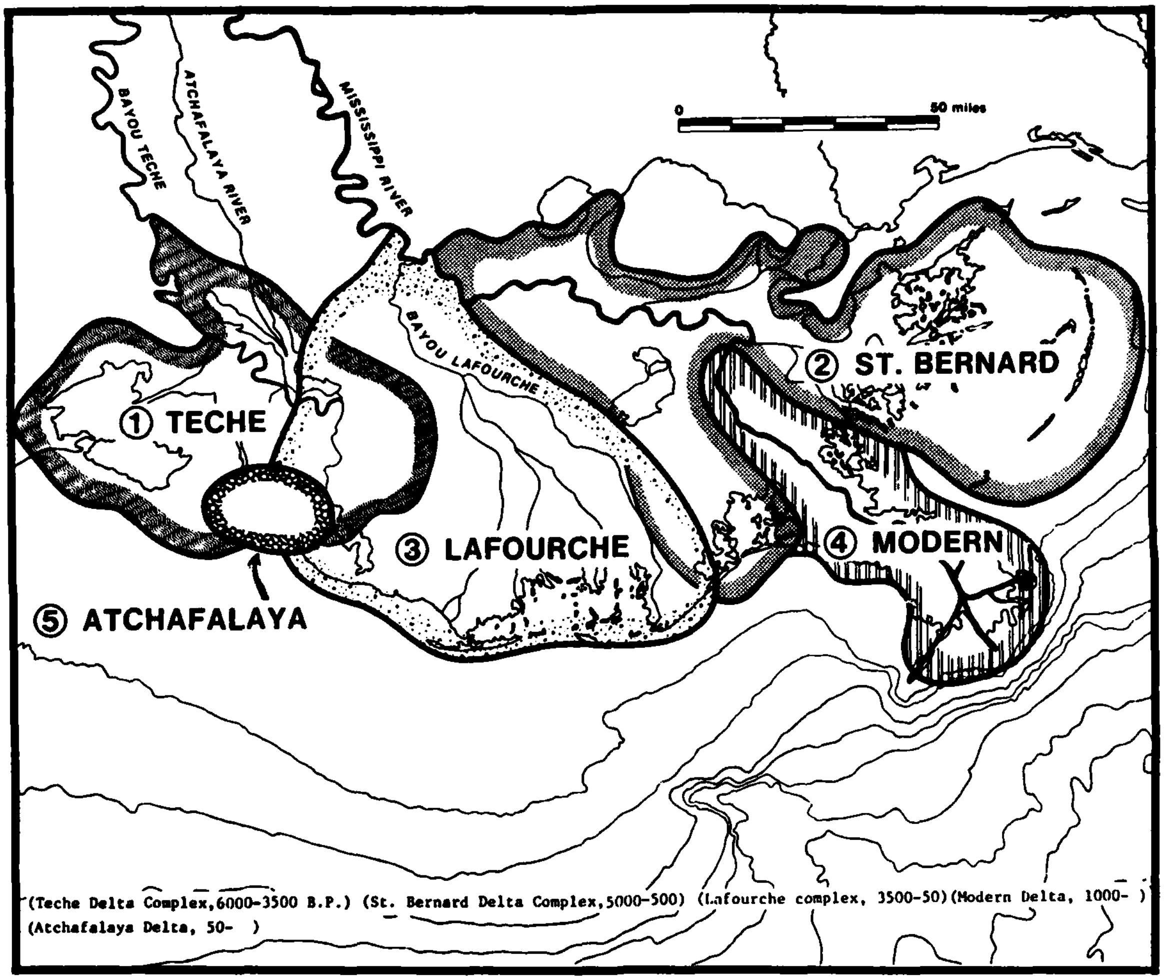

Figure 9. Large-scale diversions ofthe Mississippi River and delta systems (Van Beek et al. 1977)

42. Van Beek et al. (1977) identified distinctive phases of delta evolution as the relative importance of these processes changes. Figure 10 (Van Beek et al. 1977) illustrates a typical sequence in the life of a delta. Early in the life of a delta, soon after diversion of water and sediment to the area, the new route for the river is highly efficient and the supply of water and sediment is the dominant process (Figures 10a and 10b). Deposition occurs rapidly by whatever measure chosen. Figure 11 shows the associated area growth curve for the hypothetical delta of Figure 10.

43. The deltaic processes during rapid growth are manifested in lobe development, bifurcation, and extension of channels gulfward. With each added foot of advancement gulfward, the hydraulic efficiency of the delta as a route to the open gulf waters is diminished. The river responds by gradually shifting its load of water and sediments to other distributaries; or when the efficiency is severely reduced, new distributaries may be formed at some point upstream (Figure 10b). When the riverine supplies are curtailed, the energy for reworking the existing deposits and subsidence become more important. The second phase in the life of the delta is reached when these forces are approximately in equilibrium and there is relatively no change in the area of subaerial delta (Figures 10b and 11). During this phase, however, there is a steady but not so rapid gain in subaqueous volume of the delta. This gradual gain in subaqueous volume continues to reduce the hydraulic efficiency of the overall delta.

44. As the river continues to reroute its water and sediment away from the delta, a third phase in the delta's life is entered (Figure 10c). The riverflows have dropped to a level that will no longer maintain the myriad of distributary and finger channels in the delta, so some of these channels are abandoned. This abandonment of some secondary and tertiary channels increases the flow in the primary channels of the delta and may provide temporary new deltaic activity at the extremities of the delta. The new activity is offset, however, by the gradual loss of area from the portions of the delta that were abandoned. Overall, the delta is losing subaerial expanse (Figure 11)

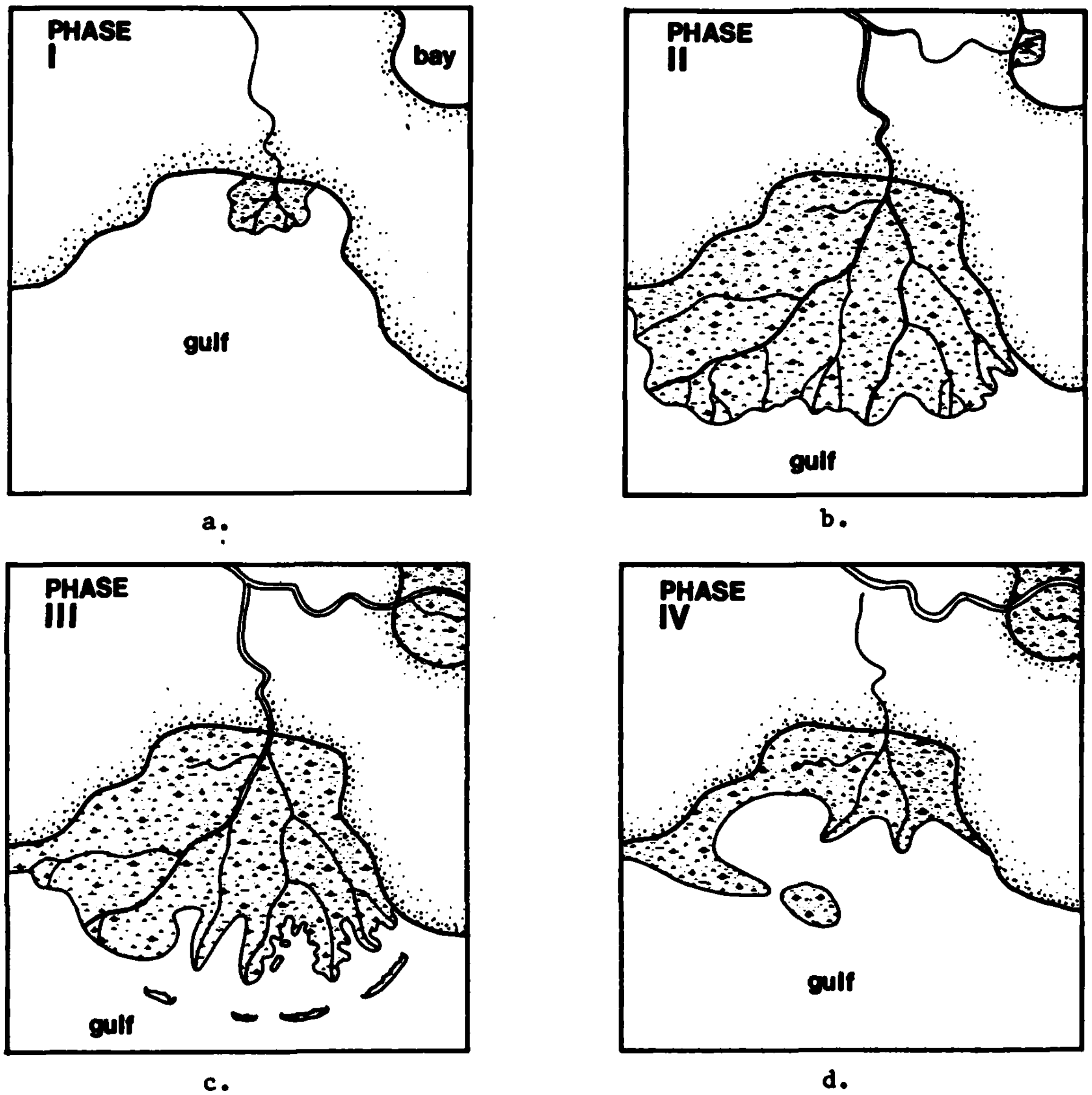

Figure 10. Phases of evolution for typical delta
(Van Beek et al. 1977)

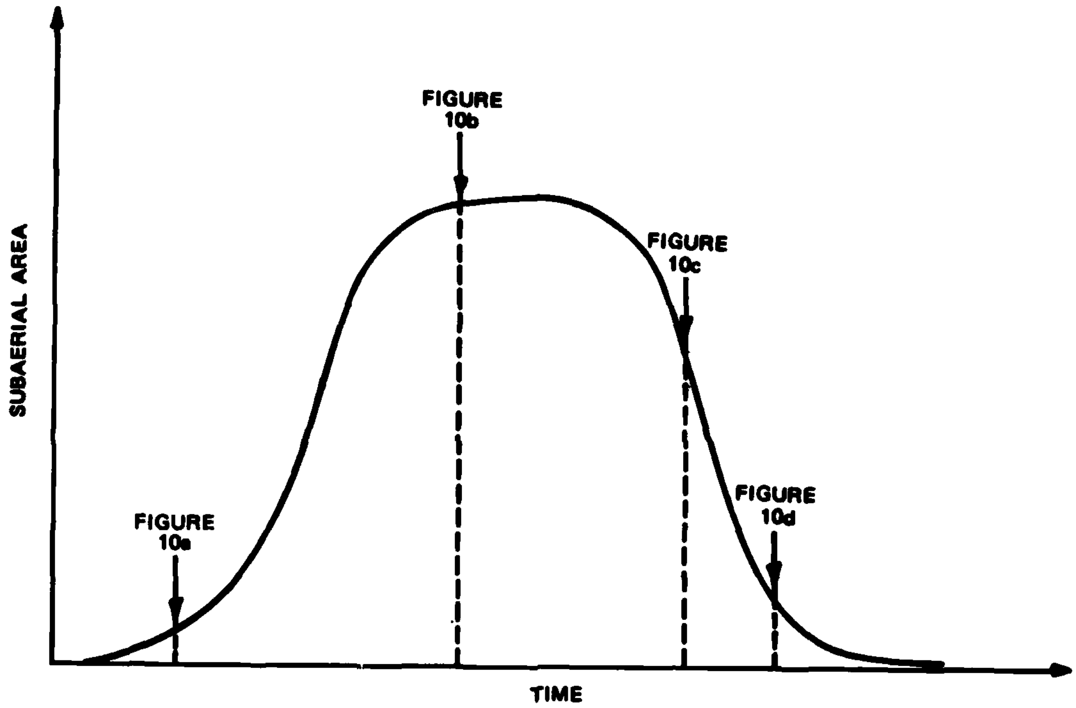

Figure 11. Delta growth cycle (after Gagliano and Van Beek 1970)

and subsidence is becoming more important, slowing the rate of volume accumulation or even halting it.

45. The final phase of the life of a delta is entered when the rate of subsidence and flushing of the system of material by the combined effects of waves and currents overshadow the supply of new sediments from the river. This phase may be gradual or abrupt, as the river is completely diverted at some point upstream (Figure 10d). The loss of both subaerial and subaqueous volume is the dominant feature as the river has moved elsewhere to build other deltas.

46. These features associated with the phases of the delta cycle can be seen in the older deltas within the Mississippi delta plain (Figure 9). Figure 12 (Van Beek et al. 1977) identifies the appropriate phases of the delta on the Louisiana coast. The Atchafalaya Bay area is the only area in the first phase of the delta growth cycle, and is being laid down atop the oldest deltaic deposits, in the final phase of an older deltaic cycle (Teche delta).

47. The Atchafalaya River has been a textbook case of the process described above. In 1839, a logjam was cleared from the Atchafalaya River near Simmesport. Many believe this removal to be the cause of the progressive increase in the amount of water entering the Atchafalaya system, while others point out that the shift was inevitable. In 1910, the Atchafalaya was receiving about 17 percent of the total flow at the latitude of Simmesport. That proportion increased to around 20 percent in 1930 and to 30 percent by 1950. The Mississippi River had become inefficient, its route to the Gulf of Mexico being approximately twice the distance of the route via the Atchafalaya. By 1950, it had become obvious that unless something was done to prevent it, the Atchafalaya River was going to capture the flow of the Mississippi and leave Baton Rouge and New Orleans without their livelihood. The Old River control structure was completed in 1963 to maintain the Atchafalaya's percentage at 30 percent.

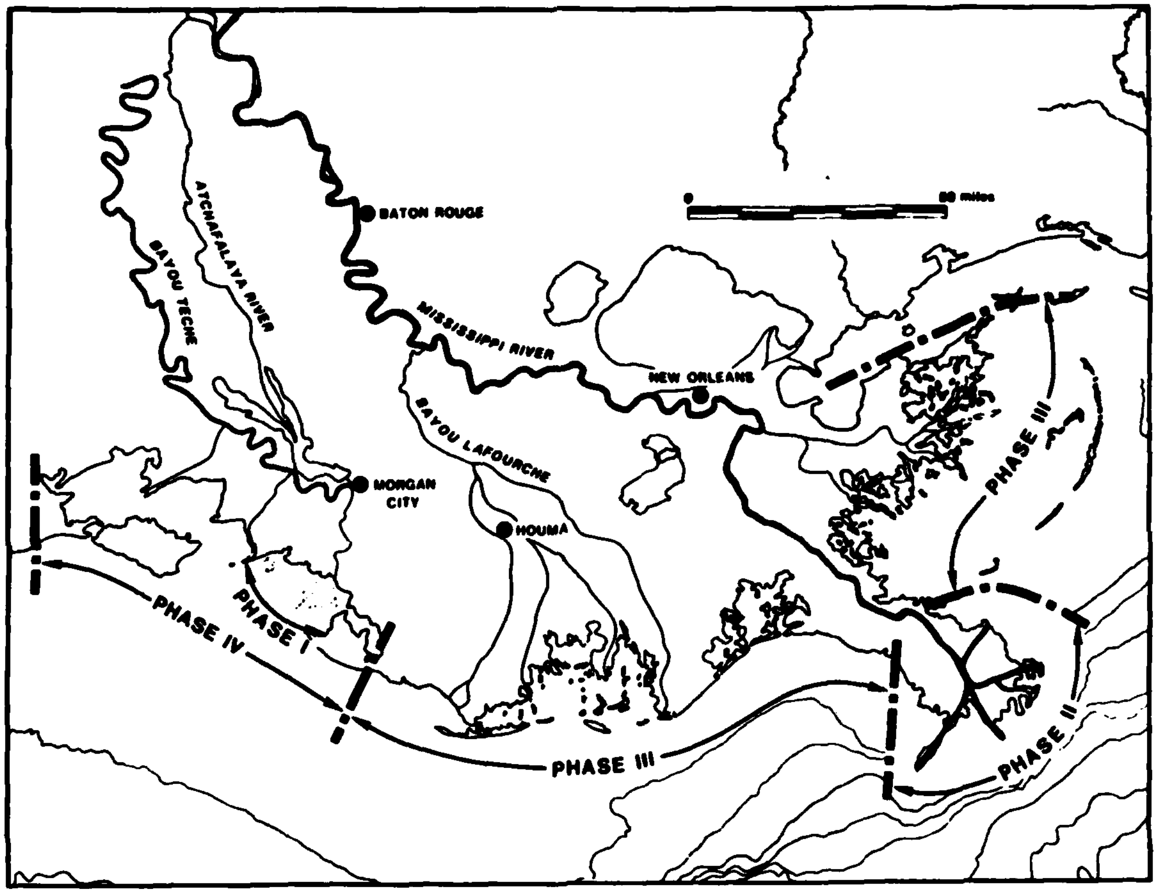

Figure 12. Current evolutionary phases of the Mississippi River subdeltas (Van Beek et al. 1977)

Previous Investigations

48. Based on the average annual sediment load into Atchafalaya Bay, Garrett, Hawxhurst, and Miller (1969) predicted the evolution of the delta within the bay through the year 2020. Figure 13 presents the predicted condition of the bay for 1975, 1980, 1990, and 2020. The contours predicted are the -1.0 ft mean low gulf (MLG) contour. The 1975 and 1980 conditions compare very well with the 1977 condition of the delta. This is remarkable, since the impact of the 1973-1975 flood years were surely unanticipated at the time of the prediction. By 1990, Garrett predicts that the delta will push beyond Point au Fer shell reef, and by 2020 be well into the Gulf of Mexico.

49. Several other investigators have speculated on the future evolution of the Atchafalaya delta. Shlemon (1975) made recommendations on how to control delta evolution by means of control structures in the dredged material placement levees adjacent to the navigation channel. Figure 14 presents Shlemon's conceptual model for subdelta controlled formation.

50. Van Beek et al. (1977) envisioned the depositional environment of the 1990's to consist of expansive subaerial delta within the bay, a delta bar, the delta front pushing beyond the shell reef, and prodelta clay deposits expanding into Cote Blanche Bays and gulfward (Figure 15). The limits of this delta condition were based on work of Garrett, Hawxhurst, and Miller (1969).

51. In the short term, Van Heerden and Roberts (1980) predicted additional subaerial development along the extremities of the existing delta in the eastern half of the Lower Atchafalaya River delta (Figure 16). They only studied the eastern half of the delta and did not address what might occur on the western side of the delta. They predicted subaqueous marine delta expansion gulfward of the reef where the navigation channel enters the gulf.

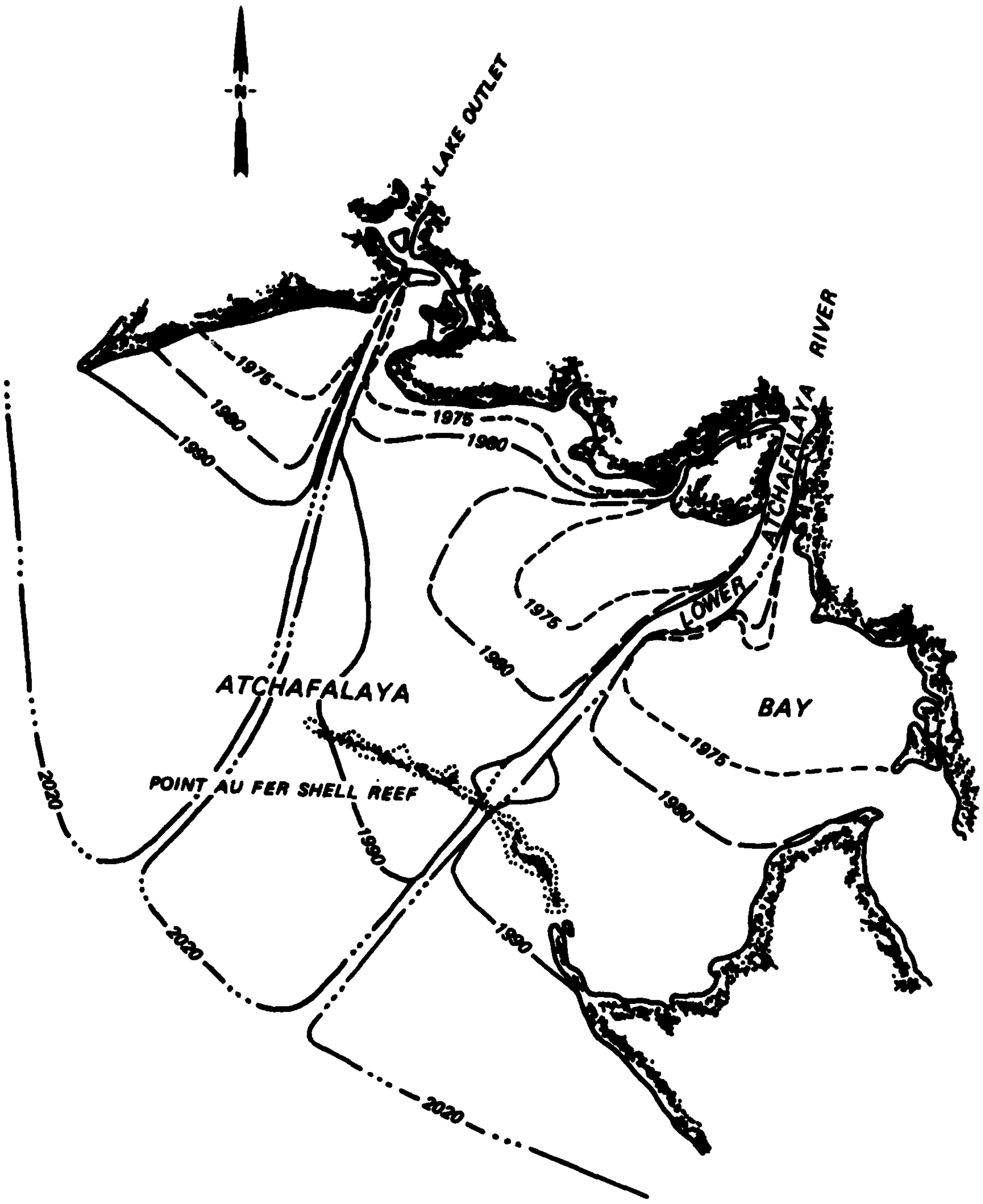

Figure 13. Predictions of delta evolution in Atchafalaya Bay (from Garrett, Hawxhurst, and Miller 1969)

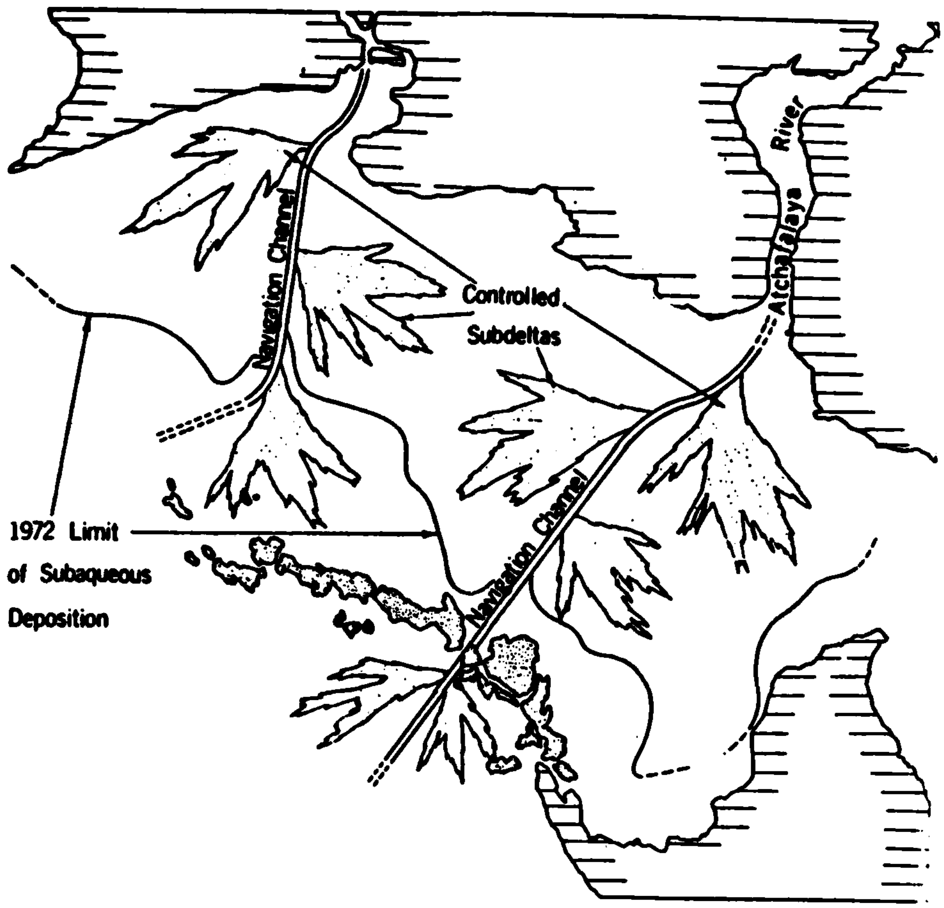

Figure 14. Suggested control of subdelta formation in Atchafalaya Bay (Shlemon 1975)

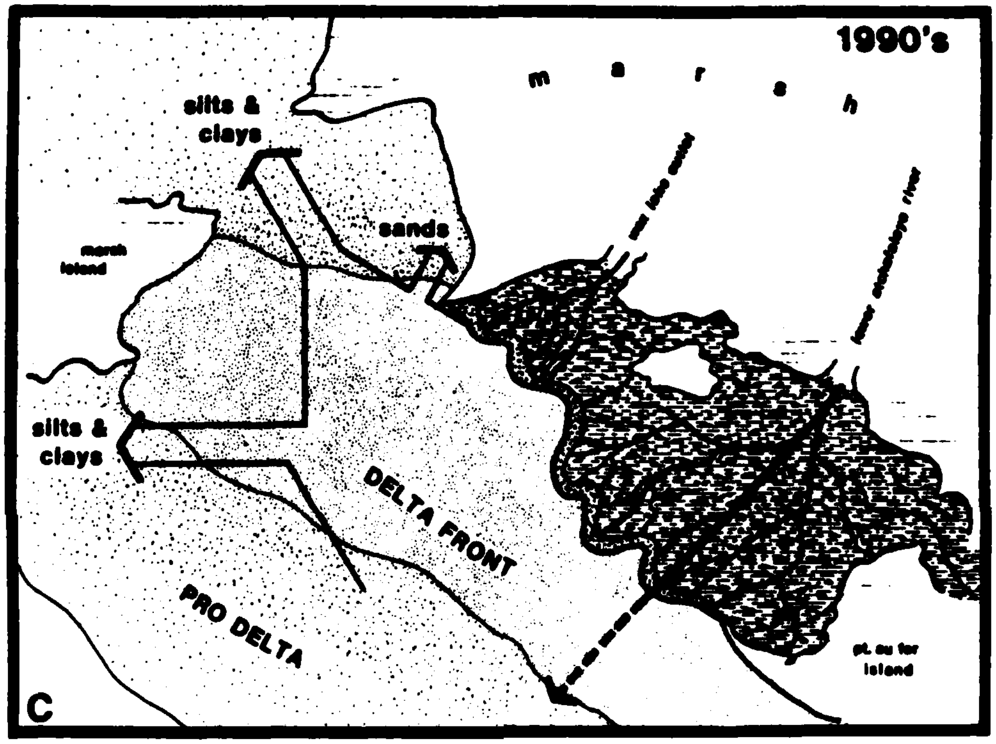

Figure 15. Deltaic processes envisioned for the 1990's
(Van Beek et al. 1977)

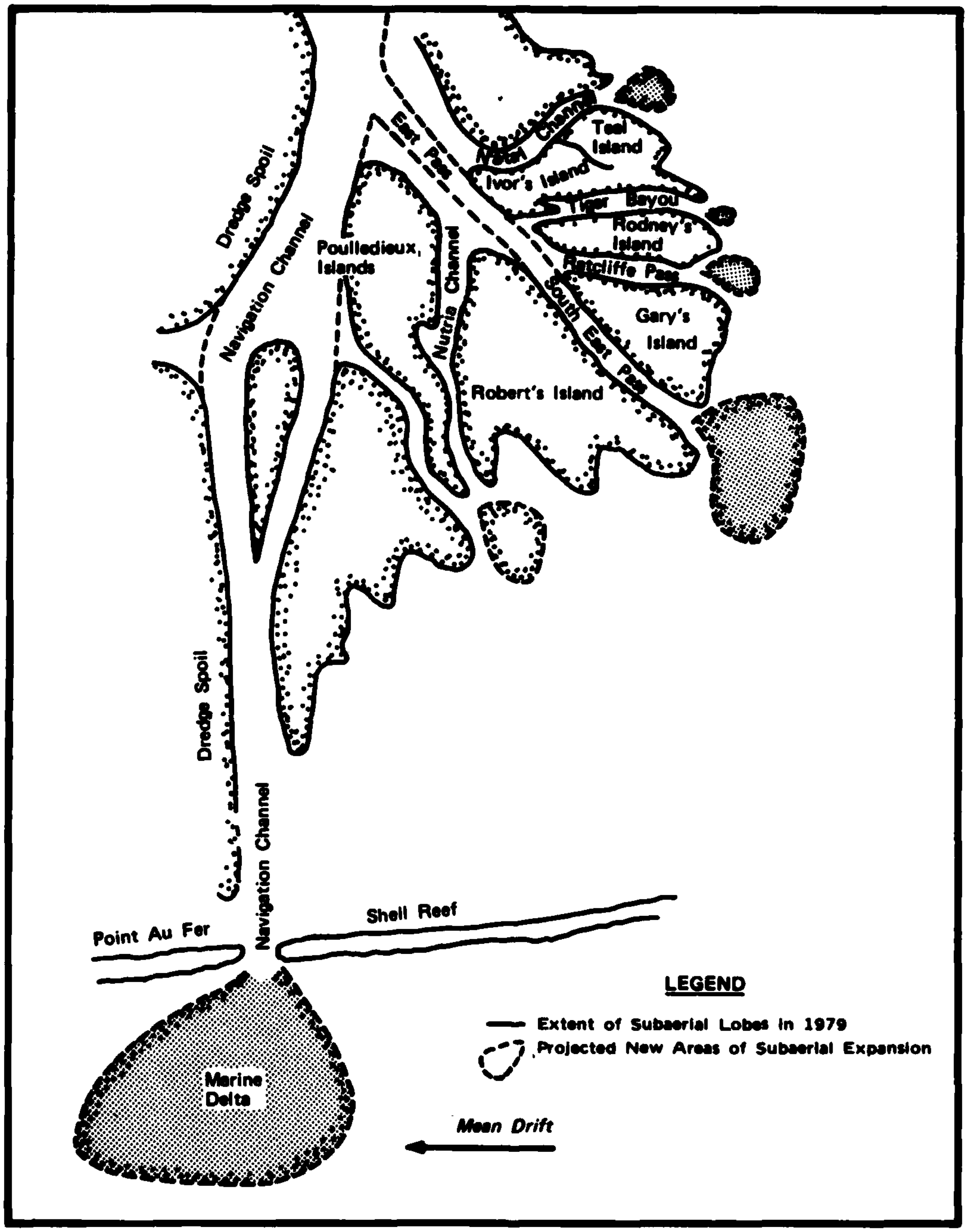

Figure 16. Predicted areas of short-term future delta growth (Van Heerden and Roberts 1980)

PART III: REGRESSION ANALYSIS

52. The desired result from the regression analysis was a predictive equation that would compute the rate of deposition (dependent variable) at a point in the bay based on a set of independent variables. All variables in the regression must either be associated with a period of time or with a point in time and with a point in space or with the system as a whole.

Regression Parameters

53. The first step in the design of the regression model was to identify the phenomena affecting deposition within Atchafalaya Bay. The following were felt to be of sufficient significance to warrant consideration.

- a. River discharge
- b. Sediment discharge
- c. Wave energy
- d. Current velocity
- e. Salinity
- f. Location with respect to the delta
- g. Water depth
- h. Present condition of the delta
- i. Bottom slope
- j. Sediment characteristics

54. The second step in the design of the regression was to determine which of the above variables were sufficiently defined by available field data to provide reasonable measure of the variation of the variable from one period of observed deposition to another. As would be expected, only a few of these variables were monitored in sufficient detail.

55. Many of the parameters of importance were not easily included in the regression due to a lack of sufficient data to reliably estimate conditions during the period. Wave energy and salinity were omitted

from consideration because of a lack of data both in space and time. Because the periods of time over which deposition occurs are long, wave energy is expected to be statistically comparable for each period. Salinity conditions vary with river discharge and over a long period, if the discharge conditions are comparable, the salinity conditions should be similar. However, if two periods had drastically different riverflows, then the salinity conditions would be expected to be dissimilar.

56. There are several variables, such as salinity, for which insufficient data are available for the periods in question. However, if these parameters are assumed to vary with another variable (river discharge for salinity), then rather than attempting to undertake a rigorous analysis to estimate the salinity condition based on river discharge and then include an estimated variable representing these salinity conditions in the regression, the salinity effects are assumed to be implicitly included in the river discharge. This is also the case for the unmeasured sediment transport near the riverbed.

57. A number of different sets of variables were tested in various forms. The independent variables ultimately included in the regression analyses were:

- a. Mean river discharge at Simmesport (in thousands of cubic feet per second).
- b. Annual sediment yield for the period (in million tons per year).
- c. Location in the bay (in thousands of feet).
- d. Center of mass of the delta, referenced in thousands of feet.
- e. Depth at the location in the bay (in feet).

Regression Approach

58. The SPSS was utilized for the analysis of prototype data and for the regression model generation. This package was used in conjunction with the DMS implemented for the total Atchafalaya Bay investigation.

59. The regression analysis was performed in two phases. First,

each variable was analyzed to provide a number of possible parameters that might be appropriate as a single-valued parameter in the regression. A simple regression was performed on each variable to identify the parameter within each group that correlated best with the observed deposition based on the simple regression coefficients. That parameter was then used in the second phase of the regression where all variables were included in the regression. The assumed form of the regression model was then varied to give the best results as measured by the regression coefficient.

60. The bay was roughly divided into two areas, one for each of the two outlets (Figure 17). The discharge at Simmesport was split between the two areas by a 70-30 percentage with the Lower Atchafalaya receiving the greater flow. The annual sediment yield was estimated at Simmesport based on a relationship between river discharge and sediment discharge.

61. The locations in the northwest portion of the bay were considered to be in the Wax Lake Outlet delta and those in the southeastern portion of the bay were associated with the Lower Atchafalaya River delta. The center of mass of each delta was computed for each of the historical bathymetric surveys, based on the volume of the delta above the -3 ft NGVD elevation. The depth was taken from the data base for the survey at the beginning of each deposition period.

Data Base

62. The basic data used for the analysis consisted of:

- a. Bathymetric surveys of Atchafalaya Bay.
- b. Discharge hydrographs at Sim esport.
- c. Suspended sediment concentrations at Simmesport.

From these basic data, all the parameters for the regression were determined.

Bathymetric data

63. The bathymetric surveys varied in spatial coverage and resolution, thereby requiring intermediate processing to permit comparison.

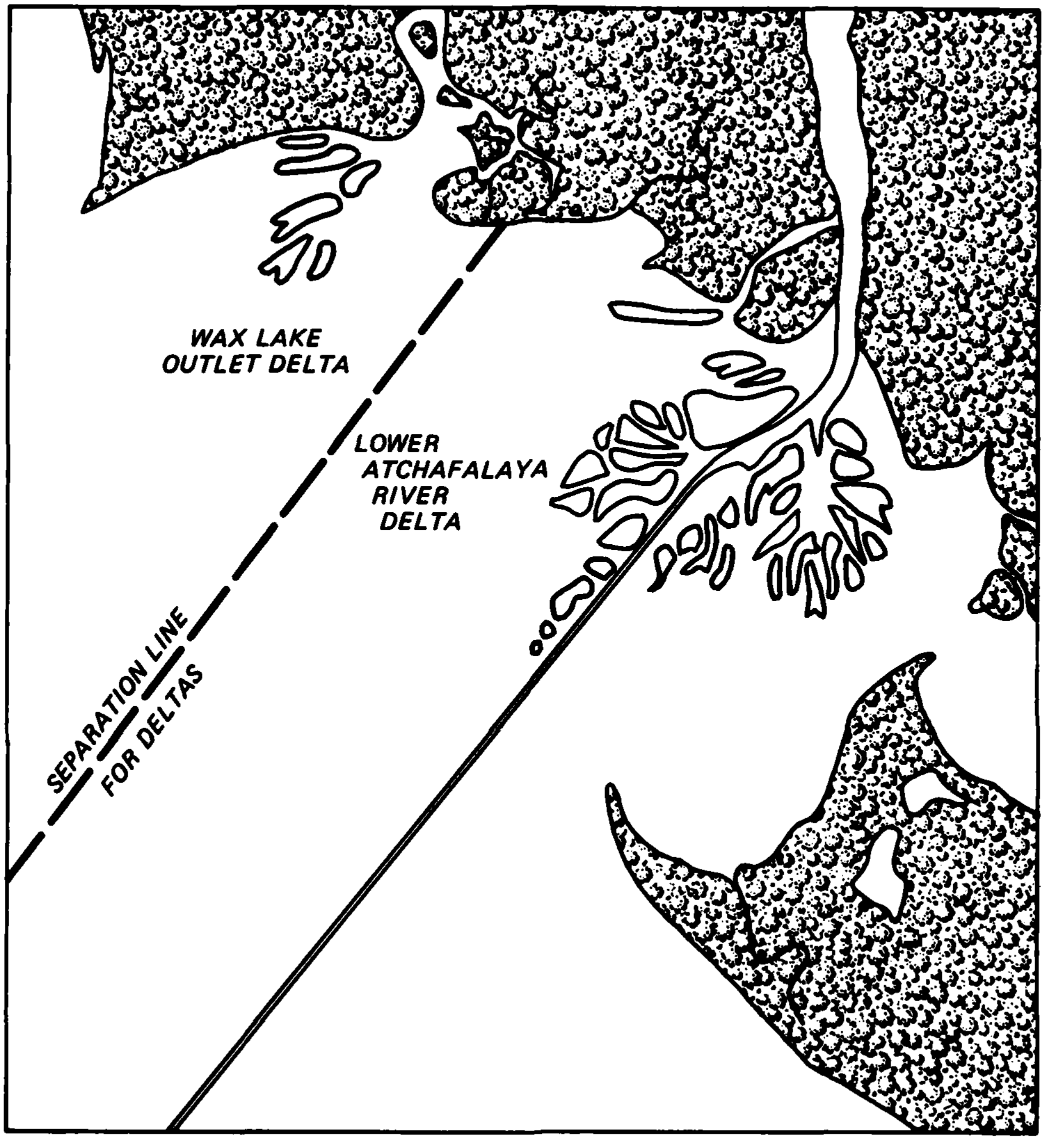

Figure 17. Separation of the bay into areas associated with the two deltas

This was accomplished by redefining the spatial coverage to a uniform 1000-ft grid oriented to Louisiana State coordinate system. The overall limits of each survey coverage, however, were retained in the new data base.

64. Initially, nine bathymetric surveys were identified and processed for inclusion in the analysis. These surveys provided general coverage of the bay for approximately seven points in time. Preliminary analysis of the data indicated problems with several of the surveys which led to their elimination from the analysis. The surveys used in the final analysis were 1961, 1967, 1972, and 1977 (Plates 5-8). The latter three surveys were LMN survey data modified by Louisiana State University to compensate for the changing datums and variation of the tides. The 1961 survey is also a LMN survey but is based on the standard method of correcting for tidal variations. This survey only covers the eastern portion of the bay.

65. These surveys were then compared to obtain the depth changes between them at each point within the 1000-ft grid where both surveys had data for comparison. This yielded three periods of change for the eastern half of the bay and only two for the western half (due to a lack of coverage in the 1961 survey).

66. The resulting bathymetric changes show little deposition during the 1961-1967 period except just west of the navigation channel (probably due to dredged material disposal). Generally, during this period, the eastern part of the bay increased in depth (Plate 9).

67. The period 1967-1972 exhibited significant deposition, particularly along the delta front within the bay as well as adjacent to the navigation channel (Plate 10). Some depth increases were observed in the center of the bay and near the reef within the bay.

68. The majority of the delta formation occurred between 1972-1977, particularly in the eastern side of the bay (Plate 11). There was still some apparent erosion in the middle of the bay and close to the reef, as the bay apparently was adjusting hydraulically to the severe changes in bathymetry. The apparent erosion observed may include the effects of subsidence.

River discharge

69. Mean daily water discharges for the period 1961-1978 (Figure 18) were analyzed statistically over subperiods corresponding to the periods between bathymetric surveys as well as over the entire period. Various parameters from the analysis were tried in the overall regression as a means of associating bathymetric change with river discharge. Results of this analysis are summarized in Table 5 for the three periods associated with the comparisons of the bathymetric surveys.

Suspended sediment concentration

70. Suspended sediment concentrations measured by LMN at Simmesport were used in combination with corresponding discharge measurements to determine the suspended sediment discharge at Simmesport. These observations were then used in a regression of suspended sediment discharge with water discharge to obtain a general expression. The computed sediment discharges are plotted versus river discharge in Figure 19. Using a power relationship, the result of the regression is

$$Q_s = 0.0728Q_w^{1.444} \tag{1}$$

where

Q_s = suspended sediment discharge in 1000 tons per day

Q_w = water discharge in 1000 cfs

The regression coefficient for the above relationship is 0.89.

Sediment yield

71. Results of the sediment discharge regression analysis expressed in Equation 1 were combined with the frequency analysis of river discharges at Simmesport to estimate the sediment yield at Simmesport.

$$S = \left(\sum_{i=1}^{N} f_i \cdot Q_{si}/DUR \right) \cdot C \tag{2}$$

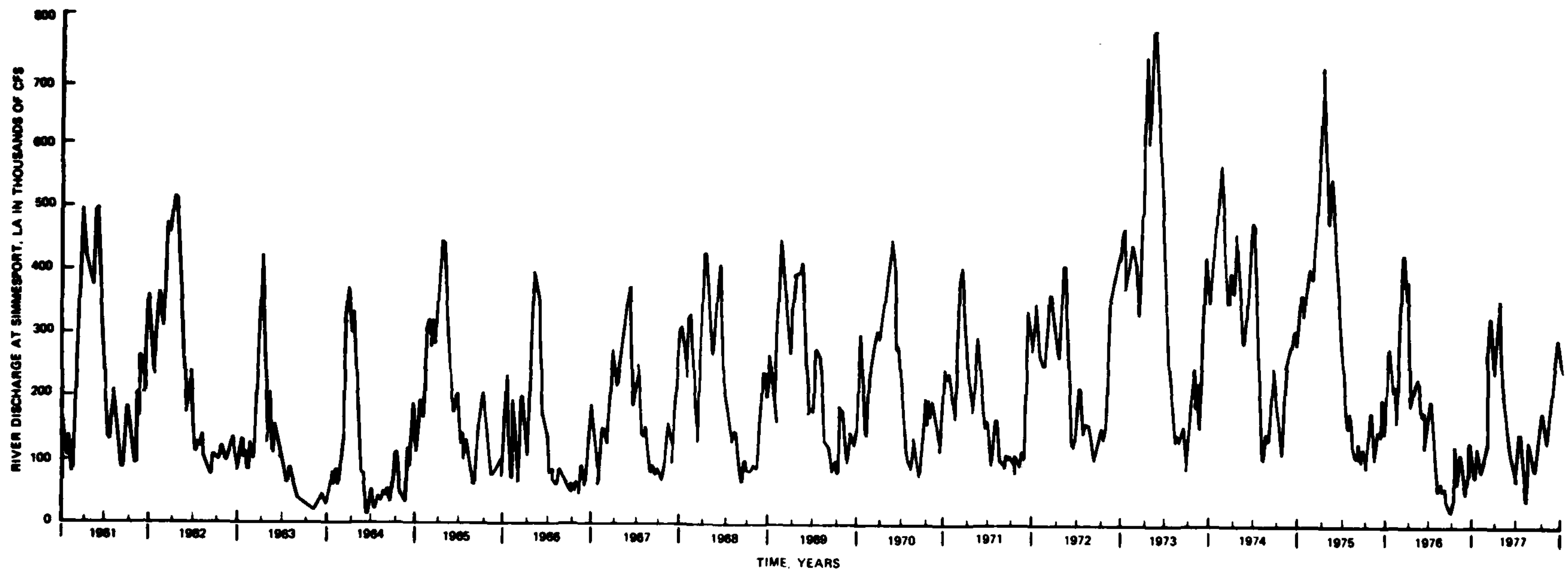

Figure 18. Discharge hydrograph for the Atchafalaya River at Simmesport, La., 1961-1977 (New Orleans District 1974)

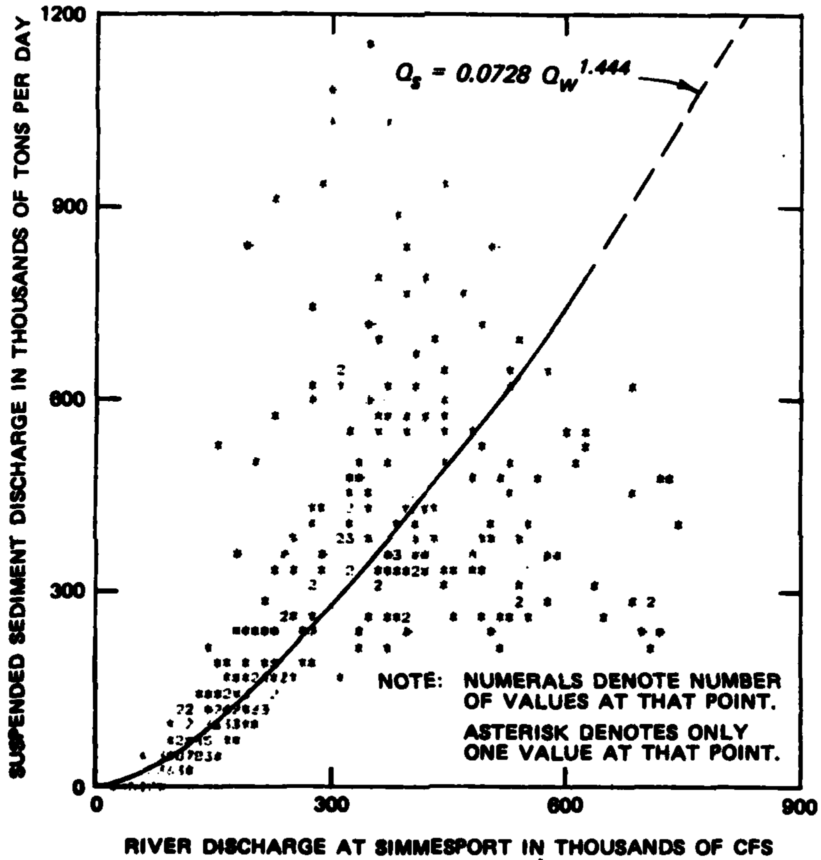

Figure 19. Relationship between river discharge and suspended sediment discharge at Simmesport, La.

where

S = sediment yield in millions of tons per year

N = number of discharge categories used in the frequency analysis

f_i = frequency of occurrence of discharge category i

Q_{si} = sediment discharge in 1000 tons per day computed from Equation 1 using Q_{wi}

Q_{wi} = river discharge in 1000 cfs for category i

DUR = duration of period

C = conversion factor from thousands of tons per day to millions of tons per year (0.365)

Results of Regression

72. The final parameter groups to be included in the regression were investigated for selection of single-valued variables that would give the best correlation with rate of deposition on a one-to-one simple regression. As discussed earlier, the mean river discharge was found suitable and intuitively appropriate as was the annual sediment yield.

73. During investigation of the use of location parameters in the analysis, two factors became important. First, the location should be expressed relative to the existing delta development. For this purpose, the location relative to the center of delta mass was chosen. Secondly, because of the dominance of river discharges on the deltaic process, the coordinate system by which the relative location is defined was oriented parallel and perpendicular to the main navigation channel, which itself runs roughly parallel to the principal direction of the riverflows as they emerge from the Lower Atchafalaya River. The location can then be thought of as having longitudinal and transverse components relative to the river discharge "jet."

74. Determination of the locations of the center of mass of the deltas was dependent on the horizontal boundaries within the bay to be associated with each delta and on the marginal depth above which the volume is to be associated with the delta. The lateral boundaries were defined mainly by the limits of the data coverage of the surveys, but in

separating the Atchafalaya delta from the Wax Lake Outlet an arbitary boundary had to be defined in the middle of the bay separating the two (Figure 17). The marginal depth of -3 ft NGVD was chosen because it is shallow enough that random undulations in the natural prodelta bathymetry would not be considered as part of the delta volume, but deep enough to include a portion of the delta front (Figure 20).

75. Use of the existing depth of the bay at a given point in time was chosen over any spatially or temporally averaged parameter in the hope that the approach would be more straightforward and that any depth dependence would not be masked by averaging. The rate of deposition for each point in the bay is plotted versus the initial depth in Plate 12 for each of the three periods. These graphs show that there is little correlation between depth and rate of deposition in a simple regression.

76. In comparing the rate of deposition with the gross spatial independent parameters--mean river discharge and sediment yield--only single-valued independent variables were available. Therefore, the mean rate of deposition was used for comparison. Table 6 gives the mean rate of deposition for the three periods along with the corresponding mean discharges and sediment yields.

77. The relationship between the rate of deposition and location in the bay is illustrated in Plates 13 and 14. The dependence of rate on the east-west coordinate, measured perpendicular to the navigation channel, positive eastward, is illustrated in Plate 13 for each of the three periods of comparison. The magnitudes of change are shown to be dependent on the discharge during the periods, with the 1972-1977 period showing the greatest change. Wax Lake Outlet is located at approximately $x = 11,000$ ft and the Lower Atchafalaya River enters the bay at about $x = 61,000$ ft. The maximum changes, both deposition and erosion, occur near these locations. The large erosion rates near the outlets could be evidence of channelization between delta lobes as the delta evolves. They could also be due to errors in horizontal control near deep channels where steep bottom slopes occur, or interpolation errors in generation of the uniform grid for survey comparison.

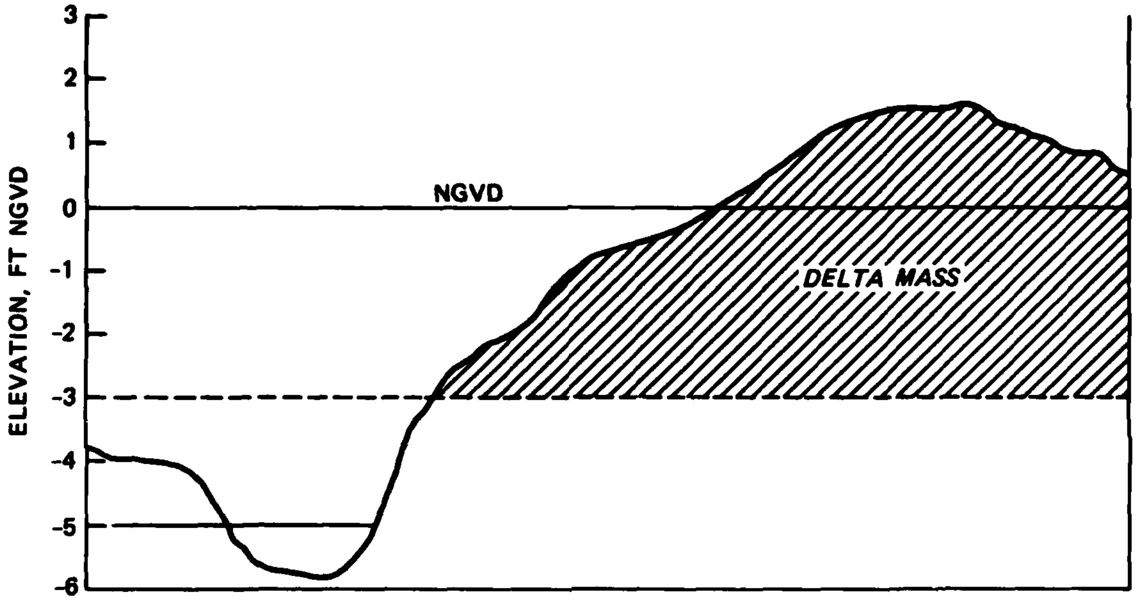

Figure 20. Definition of the delta mass for typical cross section

78. Plate 14 presents the variation in rate of deposition with the north-south coordinate, the distance along the navigation channel, positive gulfward. Eugene Island is located at approximately $y = 33{,}000$ ft. There is a great deal of scatter to the data, but a general trend from deposition toward erosion is noticeable moving in a gulfward direction. Plates 13 and 14 show that greater deposition occurs near the outlets.

79. If complex forms of equations are used in the regression, a logarithmic transformation is required in order to perform the linear regression. The logarithmic transform cannot be performed on negative rates of deposition (erosion). If negative points were simply ignored and dropped from the analysis, the mean rate of deposition would be severely biased toward deposition in the regression model. In order to include erosion rates as they influence the mean rate for the bay and allow for transformation of the equations, the zero value for the rate of deposition was shifted. The shift consisted of adding a constant to the rate of deposition such that when the logarithmic transformation was made the majority of negative rates had become positive and the mean was more nearly preserved. The magnitude of the shift was adjusted by iteration until the exponent on the sediment yield term approached unity in the results of the overall regression. The value of that shift was 0.26 ft/year. This shift was later removed when computing the deposition predictions during the extrapolation sequence. This choice of shift left many negative rates out of the regression. These large rates of erosion are felt to be associated with responses to waves, incision of channels, and other high energy processes which are not capable of being specifically addressed in such an analysis. Also, the intuitive comfort of obtaining proportionality with sediment yield outweighs any misgivings in omitting these data points.

80. The form of the mathematical equation chosen for the spatial distribution of the rate of deposition was a two-dimensional Gaussian function (a bell-shaped distribution) of the general form:

$$G = \exp\left[-\frac{(\Delta x)^2}{2\sigma_x^2}\right] \cdot \exp\left[-\frac{(\Delta y)^2}{2\sigma_y^2}\right] \qquad (3)$$

where σ_x and σ_y are constants determined from the regression. These forms of the exponential constants are used to conform to the generalized form of a Gaussian distribution. If the Δx distance is equal to σ_x, then the value is 61 percent of the peak value; equal to $2\sigma_x$, 14 percent of the peak value; $3\sigma_x$, 1 percent, etc. This form makes interpretation simpler. Further variations were tested by allowing σ_x and σ_y to vary with river discharge. These variations did not improve the results, so the simpler version with constant σ_x and σ_y was utilized.

81. If the Δx and Δy terms in the general form of the Gaussian distribution function are simply taken as the relative distance of the location in question from the centroid of delta mass, then a hidden assumption is made that the locus of deposition is independent of river discharge. To avoid making that assumption, the terms Δx and Δy were defined as

$$\begin{aligned} \Delta x &= x - \xi \\ \Delta y &= y - \zeta \end{aligned} \tag{4}$$

where

$$\begin{aligned} \xi &= x_o - AQ_m \\ \zeta &= y_o - BQ_m \end{aligned} \tag{5}$$

(ξ, ζ) is the locus of the Gaussian distribution functions, and (x_o, y_o) is the centroid of delta mass. A and B are constants to be determined from the regression and Q_m is the mean river discharge for the period in 1000's of cfs. This form of the distribution, Equation 3, allows for the river discharge to influence the distribution of sedimentation within the bay in addition to the magnitude of deposition.

82. The resultant regression equation, with appropriate constants, is the product of the distribution function, G, and a magnitude function, M.

$$\text{Deposition Rate} + \text{Shift} = G \cdot M \tag{6}$$

where

$G(x,y,x_o,y_o,Q_m)$

$$= \exp\left[-\frac{1}{2\sigma_x^2}(x - x_o + AQ_m)^2\right] \cdot \exp\left[-\frac{1}{2\sigma_y^2}(y - y_o + BQ_m)^2\right] \qquad (7)$$

and

σ_x = 30 (thousands of feet)

σ_y = 40 (thousands of feet)

A = 0.037 (1000 ft per 1000 cfs)

B = 0.094 (1000 ft per 1000 cfs)

and where

$$M(Q_m,S,d) = \exp\left(C + D \cdot Q_m^2\right) \cdot S \cdot Q_m^{0.316} \cdot d^{0.592}$$

Q_m = mean freshwater discharge, 1000 cfs

S = sediment yield, million tons per year

d = water depth, ft

C = -7.64

The added dependence of the magnitude function on Q^2 within the exponential coefficient arises from providing a means of completing the form of the Gaussian distribution in Δx and Δy involving AQ and BQ . That is,

$$D = \left(\frac{A^2}{2\sigma_x^2} + \frac{B^2}{2\sigma_y^2}\right) = 0.00000355$$

This was required because the regression analysis does not guarantee that upon expansion of the squared terms in the Gaussian distribution, the regression constants will be consistent with a squared expansion. This "correction" term in the magnitude function is very small compared with the value of C . For Q = 272,000 cfs, DQ^2 is 3 percent of C ; and $\exp(C + DQ^2)$ is 125 percent of $\exp(C)$. This variation of magnitude with discharge is consistent with other aspects of the regression.

83. The regression coefficient, R , for the overall regression was 0.465, which gives an R^2 of 0.216. This implies that the overall regression equation accounts for only about 22 percent of the total variance. The correlation matrix for the transformed variables is given in Table 7. The largest correlation coefficient (0.315) of the independent variables with $\log_e$ (Rate + Shift) is associated with $\log_e(S)$, the sediment yield term. Generally, there is not very good correlation. The basic data seem to have quite a bit of randomness in them.

84. It must be reemphasized that in the application of the regression model the units on the independent variables must be consistent with those used in the regression. These units are:

- a. All locations (x, y, x_o, and y_o) in thousands of feet
- b. Q_m , mean river discharge in thousands of cubic feet per second
- c. S , sediment yield in millions of tons per year
- d. d , depth in feet

The predicted rate of bed change is expressed in feet per year.

Properties of Regression Model

85. The regression model has certain properties of interest.

- a. The adjusted (shifted) magnitude of deposition is directly proportional to the sediment yield.
- b. Deposition has a mild dependence on depth. The rate of deposition in water depth 2d is about 24 percent greater than the rate of deposition in water depth d , with all other conditions the same.
- c. The relative location of the locus of deposition with the centroid of delta mass is dependent on river discharge.
- d. As the delta grows, the center of delta mass moves gulfward as does the locus of additional delta deposition.
- e. The exponential decay dominates as the distance from the locus grows large. For example, under the conditions of the 1972-1977 period, the deposition rate 100 miles out in the gulf at an assumed depth of 100 ft would be 0.00001 ft.

PART IV: CONFIRMATION

86. It is worthwhile to ask a few questions about the regression model. First, how well does the model represent those periods of observed bathymetric change in the prototype? Secondly, how well does the regression model extend beyond the periods over which the regression was performed? These questions can be answered by a series of confirmation test sequences applying the regression model.

87. Three confirmation sequences were performed, one each with initial bathymetry from prototype surveys of 1961, 1967, and 1972. Confirmation sequence A began with 1961 bathymetry and stepped forward to 1977. Confirmation sequence B began with the 1967 prototype bathymetry and stepped twice to 1977. The final confirmation sequence C stepped only once from initial prototype 1972 conditions to 1977.

88. The independent variable parameters input into the regression model for each of the steps of the confirmation sequences were those parameters used as input to the overall regression (Table 8) with the exception of the centroid of delta mass for the second or third steps of the sequences. The regression model predicts the thickness of the depositional blanket over the bay for each step in the sequence, then updates the depth at each point of the 1,000-ft grid over the bay. From this revised bathymetry, the new location of the center of delta mass was computed.

Confirmation Sequence A

89. Plate 15 presents the results of the first step of confirmation sequence A which began with 1961 prototype bathymetry. Comparing Plate 15 with Plate 5, the 1961 bathymetry, we see very little change due to the relatively low level of sediment inflow to the system. Comparing Plate 15 with Plate 6, the 1967 prototype data (being cautious to note the dissimilar areas of interest in the two plates), there is some resemblance between the two in the eastern end of the bay where the coverage of the two maps coincides but the -6 ft contour from the

confirmation sequence 1967 condition is much farther gulfward than that observed in the 1967 prototype condition. The areas shallower than 3 ft deep agree very well.

90. The predicted 1972 condition from confirmation sequence A is presented in Plate 16. Now the predicted condition shows the -6 ft contour well beyond Eugene Island into the gulf, while the actual 1972 condition (Plate 7) shows the -6 ft contour just approaching Eugene Island and the shell reef. Once again, however, the "delta" areas, less than 3 ft deep, agree very well in extent.

91. Plate 17 gives the final 1977 predicted condition based on initiating confirmation sequence A with 1961 bathymetry. This condition shows the -6 ft contour pushed beyond the area of interest of the 1961 survey, and the -3 ft contour beginning to push beyond the reef. This condition compares poorly with the prototype 1977 survey (Plate 8), where the -6 ft contour is just beginning to extend past Eugene Island, with the delta confined well within the bay.

92. Confirmation sequence A begins with 1961 bathymetry that is itself quite dissimilar to the 1967, 1972, and 1977 surveys in that it shows the -6 ft contour already beyond the shell reef. It is therefore not surprising that the predicted 1977 condition is so dissimilar from the prototype.

Confirmation Sequence B

93. The second confirmation sequence began with the 1967 prototype condition (Plate 6) and stepped twice to 1972 and then 1977, using the corresponding parameters during each period. Plate 18 presents the results of the first step in this sequence, the predicted 1972 condition. This condition compares very well with the actual prototype 1972 condition (Plate 7). The -6 ft contour is just starting to expand beyond the shell reef just west of the navigation channel and converges on Pt. Chevreuil at the western end of the bay. The extent of the -3 ft contour is comparable in both the predicted and the prototype.

94. The second step of confirmation sequence B predicts the 1977

condition and is shown in Plate 19. Now the predicted condition has the -6 ft contour beyond the reef and the -3 ft contour encloses about half of the bay. This is somewhat excessive deposition over what was observed as the prototype condition in 1977 (Plate 8). However, the locations of the delta development correspond fairly well.

95. Confirmation sequence B, like sequence A, predicted more deposition between the -3 and -6 ft contours, particularly in the deeper depths, than was shown by the prototype surveys.

Confirmation Sequence C

96. The final confirmation, sequence C, involves only one step in time, from the initial condition of the prototype in 1972 (Plate 7) to 1977. The predicted 1977 condition is shown in Plate 20. This prediction shows the -6 ft contour again to be beyond the reef, a feature not observed in the prototype (Plate 8). The extent of the -3 ft contour now agrees very well with its prototype location in the 1977 survey.

Quality of Confirmation

97. The confirmation sequence series has shown several items of interest.

- a. There appears to be a tendency for the regression model to overpredict deposition in deeper water.
- b. Initial bathymetry and shape of contours persist throughout each confirmation sequence. The regression model is not capable of any redistribution or readjustment of general contours as the delta evolves.
- c. Because of the method of computation of centroid of delta mass, areas of the bay without data in a given survey (Plate 7) will shift the locus of deposition to within the area of interest for that survey, and possibly cause overestimation of depositional rates on the gulfward edge of the delta.

98. The general quality of the confirmation is adequate. The best comparisons occurred, as would be expected, on the first step of each confirmation sequence; i.e., that which provided the input data

for the regression model. The further each sequence steps in time, the greater the dissimilarity with the prototype, as would be expected. These tests also emphasize how important a role a good initial bathymetric survey will play in the success of the prediction.

PART V: EXTRAPOLATION

99. The basic procedure for extrapolating into the future was developed when performing the confirmation series of tests. There are several details of the procedure that warrant further attention.

Extrapolation Procedure

100. The steps involved in the final procedure adopted for applying the regression model are:

- a. Identify the initial condition of the bathymetry in the bay.
- b. Define the centroid of mass for the Wax Lake Outlet and Lower Atchafalaya River deltas.
- c. Define the mean river discharge and sediment yield for the period of the next time-step of the extrapolation.
- d. Compute the rate of deposition at each point in the area of interest based on a or e and b and c.
- e. Adjust the previous bathymetry by the rates computed in d and the duration of the time-step.
- f. Recycle to b for new steps.

This sequence of tasks, b through e, is repeated for the number of steps to be executed by the extrapolation. For the confirmation sequences, the maximum number of steps was three (for confirmation sequence A).

Initial bathymetry

101. The initial bathymetry for the extrapolation sequence was compiled from the most current high quality maps available for all areas of the coverage displayed in the plates of this report. The basic area of this coverage is a rectangle in the Louisiana State grid coordinates (X,Y) with southwestern corner at X = 1,922,000 ft and Y = 203,000 ft and northeast corner at X = 2,037,000 ft and Y = 330,000 ft. The primary survey used for coverage within the bay was the LMN 1977 survey (Plate 8). The general coverage for the entire area of interest is presented in Plate 21. The data for the areas with no coverage in the 1977 survey were taken from NOAA-NOS chart No. 11351, 1979 edition.

Centroid of delta mass

102. The delta mass centroid was computed based on the data grid (1,000 ft) for the area of interest described above which is aligned with the Louisiana State grid. This location was then transformed into the coordinate system for the regression model which is aligned with the navigation channel.

103. The separation of the Wax Lake Outlet delta from the Lower Atchafalaya River delta was determined by the location of each point in the bay relative to an arbitrary border which lies roughly at the northwestern edge of the area of interest of the 1961 prototype survey coverage (Plate 5).

Extrapolation hydrograph

104. The extrapolation hydrograph was based on the Atchafalaya River hydrograph at Simmesport which was developed by LMN for use in the Hydrologic Engineering Center models of the Atchafalaya River basin and bay. The basic hydrograph is shown in Figure 21. The duration of the hydrograph is 50 yr, beginning with a portion of the 1974 prototype hydrograph and running through part of 1978, where it drops back to the 1949 hydrograph. Then the hydrograph follows sequentially each year through the same fraction of the 1978 hydrograph as before, whence it returns to the 1949 hydrograph and cycles up through a portion of the 1966 hydrograph.

105. The time-step for the extrapolation sequence was selected to be 2-yr intervals. Based on this selection the extrapolation hydrograph was distilled down to 25 steps with associated mean river discharges for each 2-yr period.

106. The sediment yield was computed for each 2-yr period from the discharges and durations from the basic hydrograph by use of the regression equation developed for suspended sediment transport (Equation 2). The sequence of mean discharges and sediment yields for each 2-yr step of the extrapolation are listed in Table 9. The maximum mean discharge, 310,000 cfs, occurs during the 15th step, when the 1973 flood event is included. The associated sediment yield for that period was 113 million tons per year. The minimum mean discharge occurs in the 10th event, with

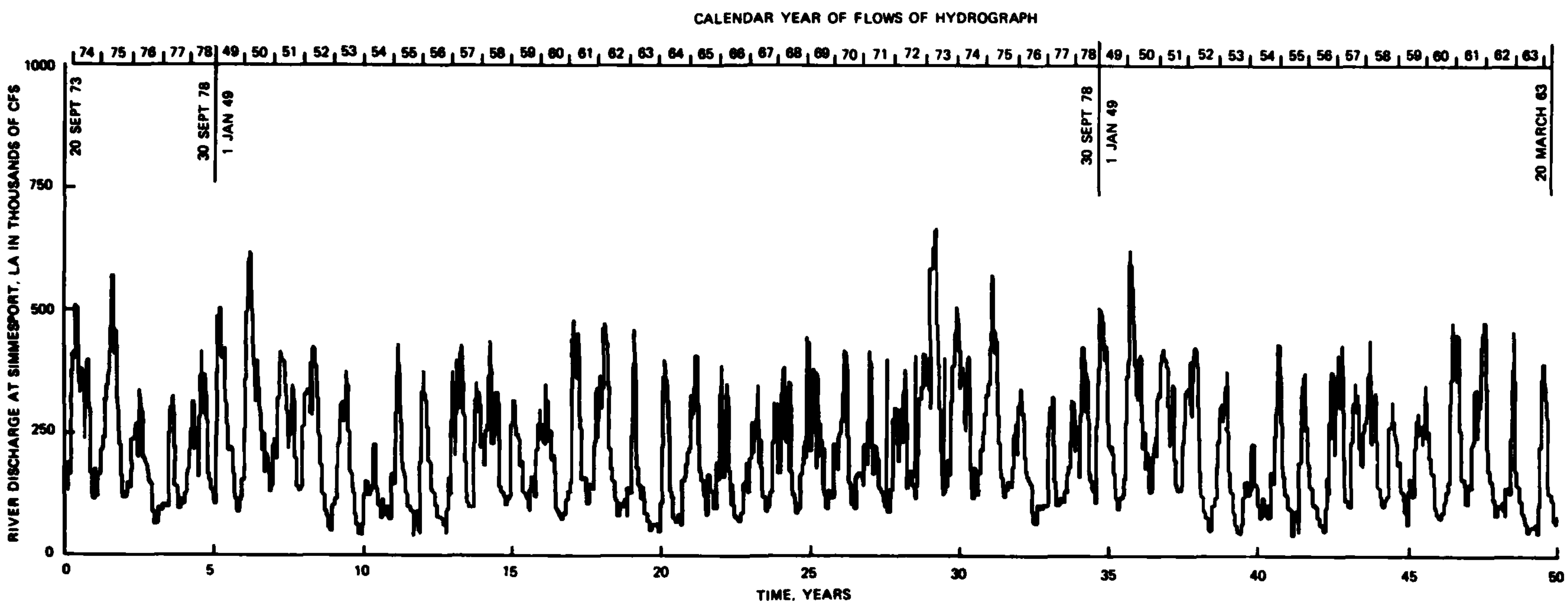

Figure 21. Fifty-year extrapolation hydrograph for Simmesport

139,000 cfs and an associated sediment yield of 38 million tons per year.

Compute rate of deposition

107. The rate of deposition is computed based on Equation 6, the regression model, with a few restrictions. The input data for the regression analysis covered periods of initial surveys (1961, 1967, and 1972) for which very few depths were shallower than 4 ft. For this reason, 4 ft was the minimum depth used in the regression equation. This results in greater rates of deposition than would otherwise have occurred in very shallow water. Basically, this recognizes the fact that the regression does not work well when the delta begins to build subaerially. As depths go negative, the power relationship with depth breaks down.

108. A rate of deposition is computed at a point in the system via the regression model for both deltas, the Wax Lake Outlet and Lower Atchafalaya River. The larger of the two computed rates is then applied at that location.

109. In computing the depositional rates for each delta, the Simmesport River discharge was split 70 percent-30 percent between the Lower Atchafalaya River and Wax Lake Outlet, respectively. The actual deposition rate was determined by removing the zero-value shift in the deposition rate that was used to include the large number of erosion data points. If after removing the shift the rate of deposition was less (more negative) than the generally accepted subsidence rate of -0.03 ft/yr, then the degree of apparent erosion was limited to the subsidence rate.

Bathymetric adjustment

110. After determining the thickness of deposition during each time-step, the deposited layer was added to the depths at the beginning of the time-step to yield the depth at the end of the time-step. The new depths were then used as the initial depth for the next time-step. An upper limit on the delta growth was assumed to be +3 ft NGVD.

Results of Extrapolation

111. The procedure described above was applied to the initial

(1977) bathymetry of Plate 21. The resulting delta conditions for 10-yr increments into the extrapolation are presented in Plates 22-26, up to year 50 of the extrapolation. Plate 27 presents the cumulative volume of deposition in the area over the period of the extrapolation. Plate 28 presents the volume of the delta as defined by the -3 ft contour versus time over the extrapolation period.

112. The first 10 yr of the extrapolation hydrograph (Figure 21) contain some substantial floods--the 1974, 1975, 1978, 1979, and 1950 flood years. Consequently, there is substantial growth of the delta during this period. The -6 ft contour has emerged beyond Point au Fer. The extent of delta has grown considerably, with the two deltas beginning to merge slightly along the northern shoreline of the bay. The total volume deposited by year 10 (1987) was 25 billion cu ft of material, and the total volume of delta was 5.87 billion cu ft, 3.85 billion of which was associated with the Lower Atchafalaya delta. This is a threefold increase in delta volume compared with the initial (1977) condition of 1.83 billion cu ft.

113. The condition of the delta after another 10 yr, at year 20 of the extrapolation (1997), is presented in Plate 23. This second 10-yr period had somewhat lower flood flows than the first 10 yr. As a result, there is very little change in the condition of the delta relative to year 10 of the extrapolation (Plate 22). The -9 ft contour did, however, continue to advance gulfward, and the gradual accumulation of material is evident as the cumulative volume curve (Plate 27) continues to increase but at a slower rate. At year 20 of the extrapolation the cumulative volume deposited has increased to 30 billion cu ft of material. The delta volume has increased to 6.6 billion cu ft. During this 10-yr period the cumulative volume increased by approximately 20 percent, while the delta volume increased by about 12 percent.

114. Plate 24 presents the condition of the bay after 30 yr of extrapolation (2007). This 10-yr period included the 1973 flood event, and its impact is evident. The -6 ft contour has been pushed almost off the map and the delta is beginning to emerge beyond the Point au Fer shell reef. The cumulative depositional volume jumped from 13 billion

cu ft to 43 billion cu ft at year 30. The delta volume (shallower than -3 ft NGVD) increased to 10.1 billion cu ft, 6.4 billion associated with the eastern delta.

115. The fourth 10-yr extrapolation period predicts to year 40 (2017). The condition at year 40 is presented in Plate 25. This period contained the same major floods as the first 10-yr period. The total volumes of water entering the system were nearly identical during the third and fourth 10-yr periods. Now the -6 ft contour is no longer in the area of interest, and the delta, as defined by the -3 ft contour, has emerged well beyond the limits of the bay (about 3 to 4 miles beyond Point au Fer). The total cumulative volume of deposition since the initial condition (1977) has increased to 54 billion cu ft and the volume of the delta has increased to 15 billion cu ft.

116. The final 10-yr period in the extrapolation had modest riverflow, and consequently, very little change in the condition of the delta can be detected (Plate 26). There is only minor change in the -3 ft contour and there is an indication of modest extension of subaerial extent. The cumulative volume for the total 50-yr hydrograph tallied out at 58 billion cu ft and the delta volume increased to 17.6 billion cu ft.

117. If a normal bulk density for the deposited sediments of 1.4 g/cu cm is assumed, then the total weight of the cumulative deposition volume is 2.55 billion tons. This is 81 percent of the total sediment yield of 3.13 billion tons transported past Simmesport for the 50-yr extrapolation hydrograph. This is of the same order of magnitude but raises the question of the trap efficiency of the bay. This percentage may be reasonable for the bay alone, but for the entire area of interest, including a portion of the gulf, it may be somewhat high. The change in wave environment from the bay to the gulf, combined with the fact that the regression model used only data from the bay in its development, makes the 81 percent trap efficiency understandable but not more reasonable. Studies on the Mississippi delta indicated that sediment retention in the delta lobes ranged from 50 to 90 percent depending on marine exposure (Gagliano and Van Beek 1970).

118. Garrett's prediction for the 1990 delta condition (Figure 13)

does not compare very well with the year 10 regression model prediction (1987, Plate 22). However, Garrett's 2020 prediction is very close to the year 40 (2017, Plate 25) and the year 50 (2027, Plate 26) predictions. This difference is to be expected, since Garrett's projections were based on a constant mean rate of deposition over the period of extrapolation and the regression model utilized an extrapolation hydrograph (Figure 21). The further into the hydrograph the regression model predicts, the closer the overall prediction will approach the mean rate prediction over the 50 yr.

PART VI: SENSITIVITY ANALYSIS

119. The sequencing and magnitude of the flows of the extrapolation hydrograph are somewhat arbitrary. The effects of the sequencing on the outcome of the extrapolation can be easily determined by a number of tests. The results of these sensitivity tests can then be compared with the original extrapolation sequence (Table 9). The sensitivity tests conducted were:

- a. The reverse sequence of the original sequence.
- b. The first 2-yr period in the sequence contains the 1973 flood event.
- c. The last 2-yr period in the sequence contains the 1973 flood event.
- d. The 2-yr period with the 1973 flood event is replaced by an average period (i.e., no 1973 flood is present).
- e. The 2-yr period with the 1973 flood event is duplicated in place of an average event (i.e., 1973 flood event occurs twice in the sequence).

The mean river discharge and sediment yields for each sensitivity test are presented in Table 10. Each sensitivity run started with the 1977 bathymetry as presented in Plate 21 and used the same extrapolation procedure as described earlier.

Reverse Sequence

120. The condition of the delta at the end of the 50-yr extrapolation hydrograph run in reverse sequence is presented in Plate 29. The cumulative volumes for each sensitivity test are presented in Plate 30. The development of the delta volume (within the -3 ft contour) with time for each sensitivity test is presented in Plate 31. A summary of the sensitivity test results is also provided in Table 11.

121. The condition of the delta using the reverse sequence is nearly identical with the condition predicted by the original sequence at year 50 of the extrapolation. The gulfward limit of the -3 ft contour

is slightly (1/2 mile) farther offshore for the reverse sequence. The magnitudes of subaerial indication are very comparable. The reverse sequence has a total cumulative volume of deposition of 60 billion cu ft, slightly greater than the 58 billion of the original sequence. The volume of the delta is 18.4 billion cu ft for the reverse sequence compared with the 17.6 billion cu ft of the original sequence at year 50, giving a 4.6 percent increase in delta volume with the reverse sequence. This sequence started with the period of low river inflows, with which the original sequence ended.

1973 Flood in First Event

122. The effect of sequencing the 1973 flood event in the first period for the extrapolation is presented in Plate 32. Again, there is little noticeable difference between the 50-yr conditions for this test over the original sequence. The -3 ft contour for this sensitivity test lies slightly closer to the shore than for the original sequence. The subaerial indications are not discernibly different. The total cumulative volume for this test, 57 billion cu ft (Table 11) is approximately 2 percent less than the volume for the original sequence. The delta volume with the 1973 flood event first is 17.3 billion cu ft at year 50, a 2 percent reduction in the size of the delta over that predicted by the original sequence.

1973 Flood in Last Event

123. Placing the 1973 flood in the last event of the extrapolation sequence will result in a predicted delta development at year 50 as shown in Plate 33. This test again shows very little difference in the condition of the delta compared with the original sequence (Plate 26). The cumulative volume of deposition is 1.7 percent greater and the delta volume is 2.3 percent greater with sequencing the 1973 flood in the last event as compared with the original sequence.

No 1973 Flood

124. Without including the 1973 flood in the extrapolation hydrograph, the total sediment yield into the bay for the 50-yr hydrograph is reduced from 3.13 billion tons with the original sequence to 3.02 billion tons, a 3.5 percent reduction. This small reduction in total sediment supply, however, effects a much larger reduction in total cumulative depositional volumes and volumes of the delta. The cumulative volume is reduced to 49 billion cu ft, a 15.5 percent reduction from the original sequence test, and the delta volume at year 50 is reduced to 12.6 billion cu ft, a 28.4 percent reduction.

125. Result of the extrapolation without a 1973 flood event is presented in Plate 34. There is now a noticeable difference in the condition of the delta. The -3 ft contour is 1 to 2 miles closer to shore without the 1973 flood event, and there are still regions within the bay shallower than 3 ft deep. The indication of subaerial delta development is substantially reduced.

1973 Flood Event Included Twice

126. Including the 1973 flood twice during the extrapolation hydrograph has a noticeable impact on the condition of the delta at 50 yr (Plate 35). The -3 ft contour is displaced 1 to 2 miles farther gulfward, and the indication of subaerial growth has increased greatly over that observed from the original sequence.

127. The increased riverflows also provided an increase of 3.5 percent sediment yield supplied to the bay over the 50 yr of the extrapolation. Once again, as with the no 1973 flood test, a small change in sediment supply causes large increases in impact on the bay. The cumulative volume of deposition increased 13.8 percent to 66 billion cu ft, and the delta volume increased 26.1 percent to 22.2 billion cu ft with the 1973 flood included twice compared with the original sequence.

Summary

128. These last two sensitivity tests had noticeably different

50-yr delta conditions compared with the original sequence, due to their different sediment yields and riverflows reaching the system. However, for the first three sensitivity tests, which all had the same total supplies of sediment and water to the system, there was no significant difference in the predicted 50-yr condition.

129. Also included in Table 11 is a column presenting the percentage of the total sediment yield that is retained in the area of interest. It is interesting to note that the greater the total sediment yield, the greater percentage of that yield is retained. This could be a phenomenological effect related to the higher riverflows associated with the higher yields, or it could simply be a reflection of the fact that the limits of the area of interest for computation of the retention was very close to the delta limits.

PART VII: LIMITATIONS AND RECOMMENDATIONS

130. There are certain limitations of the overall method of extrapolation that should be clearly noted. Also, insights gained into the regression model and the extrapolation by their application can be used to guide future refinements. Therefore, some recommendations should be made.

Limitations

131. The method developed for this study for predicting the evaluation of a delta system has certain limitations.

- a. This method is a statistical tool only. It is not a dynamic model.
- b. The results can only be as good as the quality of the input data for the regression analysis.
- c. The regression model was developed from data within the bay, which is protected from the gulf wave environment. Applying the model to delta development beyond the bay will therefore not be as valid as its application within the bay.
- d. Within the bay, the regression model does not have the ability to address the impact that the growing delta has on bay hydrodynamics. As the depositional environment within the bay changes, the applicability of the regression model could become questionable even there.
- e. The regression model's inability to realistically address the transformation from subaqueous to subaerial delta is acknowledged. This, however, is primarily due to a lack of sufficient data. Once adequate data are collected, this could be addressed in future work.
- f. The predicted condition of the delta in form and shape is heavily dependent on the initial condition from which the extrapolation is based. Therefore, care must be exercised to guarantee that erroneous initial conditions are not used.

132. These limitations are noted so that the reader will not be misled about the capabilities of this method. However, it is firmly believed that for the level of sophistication required, this approach and method are the best available without proceeding to actual dynamic modeling.

Recommendations

133. Several recommendations can now be made for consideration in future refinements to the technique, whether reapplied to the Atchafalaya Bay area or the other areas.

a. Anticipate changes in the depositional environment during delta evolution and provide, if data are available, parameters in the regression model to address these changes (e.g., wave climate for the gulf environment relative to the bay environment).

b. Structure parameters for the regression equation in a nondimensional way to avoid problems with units.

c. Divide the analysis into several regression models, for different areas of the delta (e.g., prodelta, delta front, and lobe environment). The choice of which regression model to apply could be made based on a variety of parameters.

d. As very recent hydrologic data become available, a test should be made with the actual hydrograph from 1977 through 1981 to check the method's ability to predict over a period for which the data were not used in the regression.

PART VIII: CONCLUSIONS

134. The following conclusions have been drawn from the results of this study:

a. It is highly likely that the delta in Atchafalaya Bay will expand beyond the Point au Fer shell reef during the next 50 yr.

b. The order in which the hydrologic events are processed through the extrapolation method does not significantly impact on the predicted ultimate condition of the delta at a point in time, provided the total volumes of sediments and water entering the system up to that point in time are fixed.

c. The transition from subaqueous to subaerial delta is not handled accurately by the regression model reported herein.

d. The −3 ft contour is the most appropriate indicator of the delta evolution for interpreting the results reported herein.

e. The framework has been developed with which to update, improve, and reapply the extrapolation regression model with greater and greater degrees of confidence in the future.

f. The predictions reported herein are in very good agreement with the predictions made by Garrett, Hawxhurst, and Miller (1969).

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Table 1

Maintenance Dredging in Lower Atchafalaya River

Fiscal Year	Volume of Dredging millions of cu yd	Controlling Depth, ft Below Mean Low Gulf
1913	3.111	20
1914	2.001	19
1915	1.199	18
1919	3.202	14
1939	0.082	10
1947	0.395	6
1948	0.830	10
1958	1.938	14
1960	2.400	12
1961	2.485	18
1962	3.004	16
1964	3.003	10
1965	3.903	12
1966	3.025	16
1967	1.240	13
1968	0.643	10
1969	1.190	17
1970	1.925	16
1971	1.032	16
1072	1.597	16
1973	2.566	*
1974	7.842	*
1975	0.881	*

* No data available.
Source of data: Office, Chief of Engineers (1913-1975).

Table 2

Tidal Characteristics

	Morgan City	Calumet	Eugene Island
Tide Ranges, ft:			
Extreme spring	3.9	3.8	—
Mean diurnal	1.3	1.4	1.9
Elevations, ft NGVD:			
Mean high water	1.9	1.9	—
Mean low water	0.75	0.84	—
Effects of hurricanes (maximum high water)	8.5	8.3	6.8
Effects of northerly storms (maximum low water)	-2.3	-2.8	-3.5

Source of data: Garrett, Hawxhurst, and Miller (1969).

Table 3

Tropical Storms in the Gulf of Mexico, 1950-1973

No.	Date	Name	Class*	Landfall
1	Aug 27-31, 1950	Baker	H	Alabama
2	Sep 3-7, 1950	Easy	H	Florida
3	Oct 1-4, 1950	How	T	Mexico
4	Oct 8-10, 1950	Item	H	Mexico
5	Oct 17-21, 1950	Love	H	Florida
6	Aug 20-22, 1951	Charlie	H	Mexico
7	Sep 20-21, 1951	George	T	Mexico
8	Sep 29-Oct 2, 1951	How	T	Florida
9	Jun 1-6, 1953	Alice	T	Florida
10	Aug 28-30, 1953	—	T	Florida
11	Sep 14-20, 1953	—	T	Florida
12	Sep 24-28, 1953	Florence	H	Florida
13	Oct 7-9, 1953	Hazel	T	Florida
14	Jun 24-26, 1954	Alice	H	Mexico
15	Jul 27-29, 1954	Barbara	T	Louisiana
16	Sep 11-12, 1954	Florence	H	Mexico
17	Jul 31-Aug 2, 1955	Brenda	T	Louisiana
18	Aug 25-29, 1955	—	T	Louisiana
19	Sep 4-6, 1955	Gladys	H	Mexico
20	Sep 17-19, 1955	Hilda	H	Mexico
21	Sep 28-29, 1955	Janet	H	Mexico
22	Jun 11-14, 1956	—	T	Louisiana
23	Jul 25-26, 1956	Anna	H	Mexico
24	Sep 10-12, 1956	Dora	T	Mexico
25	Sep 22-25, 1956	Flossy	H	Louisiana/Florida
26	Jun 8-9, 1957	—	T	Florida
27	Jun 25-28, 1957	Audrey	H	Texas/Louisiana
28	Aug 8-11, 1957	Bertha	T	Louisiana
29	Sep 7-8, 1957	Debbie	T	Florida
30	Sep 16-19, 1957	Ester	T	Louisiana
31	Jun 14-16, 1958	Alma	T	Mexico
32	Sep 3-6, 1958	Ella	H	Texas
33	May 28-Jun 2, 1958	Arlene	T	Louisiana
34	Jun 15-18, 1959	Beulah	T	Mexico
35	Jul 22-25, 1959	Debra	H	Texas

(Continued)

* Hurricane (H), Tropical storm (T).
Source of data: American Meteorological Society (1950-1973).

Table 3 (Concluded)

No.	Date	Name	Class	Landfall
36	Oct 6-8, 1959	Irene	T	Alabama
37	Oct 17-18, 1959	Judith	H	Florida
38	Jun 22-28, 1960	—	T	Texas
39	Sep 9-11, 1960	Donna	H	Florida
40	Sep 14-16, 1960	Ethel	H	Alabama
41	Sep 8-12, 1961	Carla	H	Texas
42	Nov 4-8, 1961	Inga	T	Stayed off coast of Mexico
43	Sep 16-19, 1963	Cindy	H	Texas
44	Jun 2-11, 1964	—	T	Florida
45	Aug 5-8, 1964	Abbey	H	Texas
46	Sep 30-Oct 4, 1964	Hilda	H	Louisiana
47	Oct 13-15, 1964	Isbell	H	Florida
48	Jun 12-15, 1965	—	T	Florida
49	Sep 8-10, 1965	Betsy	H	Louisiana
50	Sep 26-30, 1965	Debbie	T	Alabama
51	Jun 8-10, 1966	Alma	H	Florida
52	Sep 20-21, 1966	Hallie	T	Mexico
53	Oct 5-11, 1966	Inez	H	Mexico
54	Sep 17-22, 1967	Beulah	H	Texas
55	Oct 1-4, 1967	Fern	H	Mexico
56	Jun 2-5, 1968	Abbey	H	Florida
57	Jun 22-24, 1968	Candy	T	Texas
58	Oct 16-19, 1968	Gladys	H	Florida
59	Aug 15-19, 1969	Camille	H	Mississippi
60	Oct 1-6, 1969	Jenny	T	Florida
61	Oct 19-27, 1969	Laurie	H	Mexico
62	Jul 19-23, 1970	Becky	T	Florida
63	Jul 31-Aug 5, 1970	Celia	H	Texas
64	Sep 10-13, 1970	Ella	H	Mexico
65	Sep 14-17, 1970	Felice	T	Texas
66	Sep 3-13, 1971	Fern	H	Louisiana/Texas
67	Sep 11-17, 1971	Edith	H	Louisiana
68	Jun 14-20, 1972	Agnes	H	Florida
69	Aug 18-22, 1973	Brenda	H	Mexico
70	Sep 1-7, 1973	Delia	T	Texas

Table 4

Average Annual Suspended Load Budget, Atchafalaya River

	Input at Simmesport		Distribution of Input					
			Basin Retention		Wax Lake Outlet		Atchafalaya River	
	million tons/yr	Percent	million tons/yr	Percent	million tons/yr	Percent	million tons/yr	Percent
1967–1971								
Sand	19.3	22	14.5	75	1.1	6	3.7	19
Silt/clay	67.9	78	10.2	15	15.6	23	42.1	62
Total	87.2	100	24.7	29	16.7	19	45.8	52
1973–1975								
Sand	37.5	25	3.7	10	5.7	15	28.1	75
Silt/clay	110.7	75	21.2	19	21.8	20	67.6	61
Total	148.2	100	24.9	17	27.5	19	95.7	65

Source of data: Roberts, Adams, and Cunningham (1980).

Table 5

Analysis of Daily Water Discharge, 1961-1977

Period	Duration days	Discharge Parameter, 1000 cfs Mean	Minimum	Maximum	Standard Deviation
1961-1967	2329	168	11	510	122
1967-1972	1810	211	65	450	101
1972-1977	1765	272	22	781	164
1961-1977	5904	212	11	781	137

Table 6

Average Rates of Deposition

Period	Average Deposition Rate ft/yr	Mean Discharge 1000 cfs	Annual Sediment Yield 10^6 tons/yr
1961-1967	-0.087	168	50
1967-1972	+0.057	211	64
1972-1977	+0.129	272	97

Table 7

Correlation Matrix for Regression Analysis

Parameter	Correlation Coefficient							
	1	2	3	4	5	6	7	8
ln (Rate + Shift)	1.000	−0.169	−0.172	−0.083	−0.132	0.024	0.315	0.061
$(x - x_o)^2$	−0.169	1.000	0.154	0.167	−0.169	0.211	0.064	0.074
$(y - y_o)^2$	−0.172	0.154	1.000	−0.290	0.894	0.263	0.068	0.423
$(x - x_o)Q$	−0.083	0.167	−0.290	1.000	−0.245	−0.028	−0.013	−0.062
$(y - y_o)Q$	−0.132	−0.169	0.894	−0.245	1.000	0.484	0.190	0.313
$\log_e(Q)$	0.024	0.211	0.263	−0.028	0.484	1.000	0.293	−0.266
$\log_e(S)$	0.315	0.064	0.068	−0.013	0.190	0.293	1.000	−0.011
$\log_e(d)$	0.061	0.074	0.423	−0.062	0.313	−0.266	−0.011	1.000

Table 8

Confirmation Sequence Input

Period	Duration days	Mean River Discharge 1000 cfs	Sediment Yield 10^6 tons/yr	Step Number for Confirmation Sequence		
				A	B	C
1961 to 1967	2329	168	50	1	-	-
1967 to 1972	1810	211	64	2	1	-
1972 to 1977	1765	272	97	3	2	1

Table 9

Extrapolation Parameters

Step No.	Mean River Discharge, 1000 cfs	Sediment Yield 10^6 tons/yr
1	275	94
2	153	40
3	231	74
4	284	98
5	175	53
6	152	42
7	198	61
8	197	57
9	219	70
10	139	38
11	170	48
12	176	50
13	199	59
14	183	52
15	310	113
16	220	69
17	175	50
18	265	91
19	230	75
20	147	40
21	162	47
22	224	70
23	192	58
24	198	61
25	185	56

Note: Each step consists of 2 yr.

Table 10

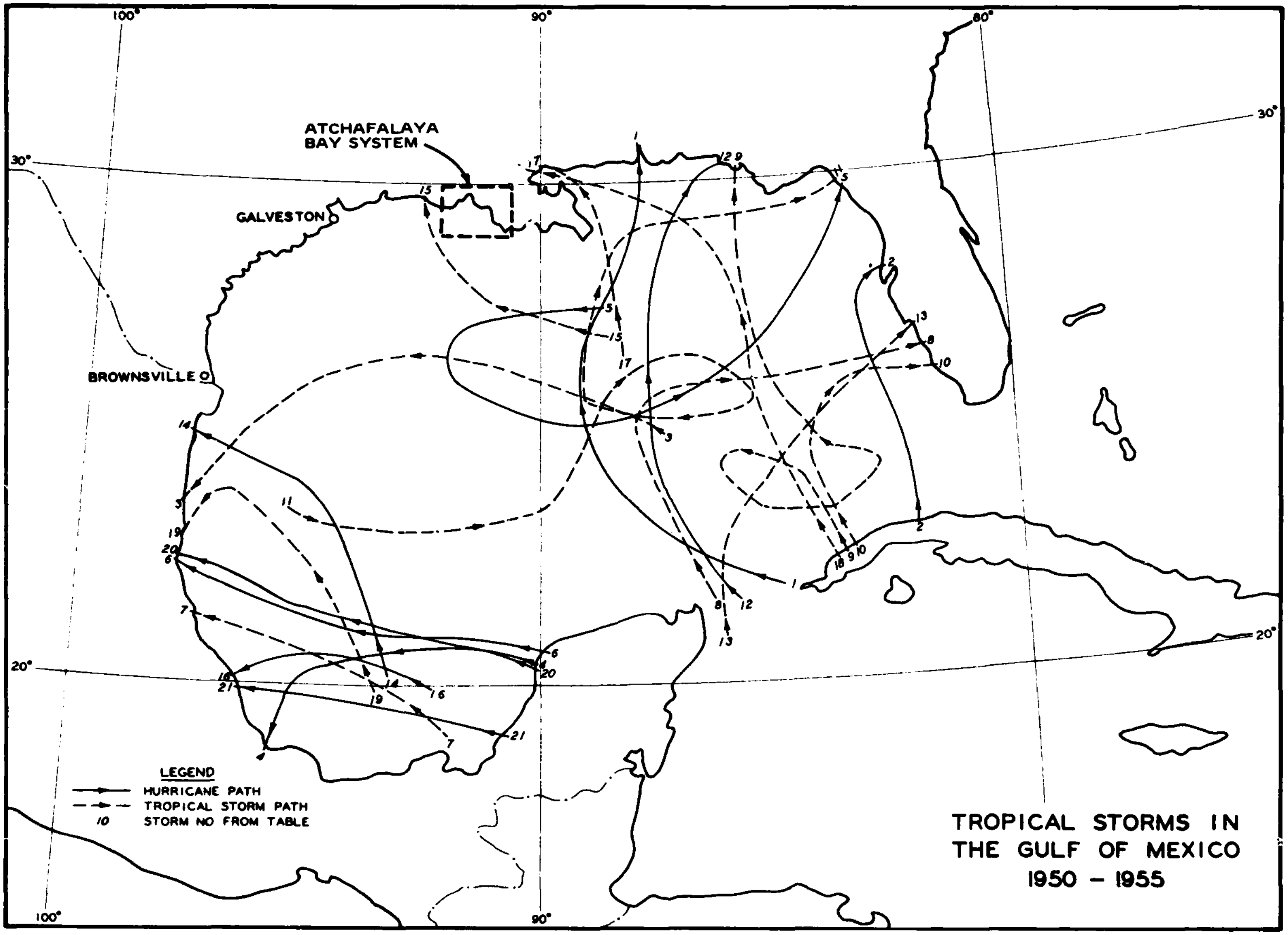
Inputs for Sensitivity Analysis

Step No.	Inputs at Simmesport Mean Discharge (1000 cfs)/Sediment Yield (10^6 tons/yr)					
	Original Sequence	Reverse Sequence	1973 Flood First Event	1973 Flood Last Event	No 1973 Flood	1973 Flood Twice
1	275/94	185/56	310/113	220/69	275/94	275/94
2	153/40	198/61	220/69	175/50	153/40	153/40
3	231/74	192/58	175/50	265/91	231/74	231/74
4	284/98	224/70	265/91	230/75	284/98	284/98
5	175/53	162/47	230/75	147/40	175/53	175/53
6	152/42	147/40	147/40	162/47	152/42	152/42
7	198/61	230/75	162/47	224/70	198/61	310/113
8	197/57	265/91	224/70	192/58	197/57	197/57
9	219/70	175/50	192/58	198/61	219/70	219/70
10	139/38	220/69	198/61	185/56	139/38	139/38
11	170/48	310/113	185/56	275/94	170/48	170/48
12	176/50	183/52	275/94	153/40	176/50	176/50
13	199/59	199/59	153/40	231/74	199/59	199/59
14	183/52	176/50	231/74	284/98	183/52	183/52
15	310/113	170/48	284/98	175/53	199/59	310/211
16	220/69	139/38	175/53	152/42	220/69	220/113
17	175/50	219/70	152/42	198/61	175/50	175/50
18	265/91	197/57	198/61	197/57	265/91	265/91
19	230/75	198/61	197/57	219/70	230/75	230/75
20	147/40	152/42	219/70	139/38	147/40	147/40
21	162/47	175/53	139/38	170/48	162/47	162/47
22	224/70	284/98	170/48	176/50	224/70	224/70
23	192/58	231/74	176/50	199/59	192/58	192/58
24	198/61	153/40	199/59	183/52	198/61	198/61
25	185/56	275/94	183/52	310/113	185/56	185/56

Table 11

Summary of Sensitivity Tests

Test	Total Sediment Yield billion tons	Sediment Yield Ratio	Cumulative Volume billion ft^2	Percent Retention	Cumulative Volume Ratio	Delta Volume billion ft^3	Delta Volume Ratio
Original sequence	3.13	1.000	58	81	1.000	17.6	1.000
Reverse sequence	3.13	1.000	60	84	1.035	18.4	1.046
1973 event first	3.13	1.000	57	79	0.983	17.3	0.983
1973 event last	3.13	1.000	59	83	1.017	18.0	1.023
No 1973 event	3.02	0.965	49	71	0.845	12.6	0.716
1973 flood twice	3.24	1.035	66	85	1.138	22.2	1.261



ATCHAFALAYA BAY SYSTEM
GALVESTON
BROWNSVILLE
LEGEND
HURRICANE PATH
TROPICAL STORM PATH
10 STORM NO FROM TABLE
TROPICAL STORMS IN THE GULF OF MEXICO 1950 - 1955

PLATE 1

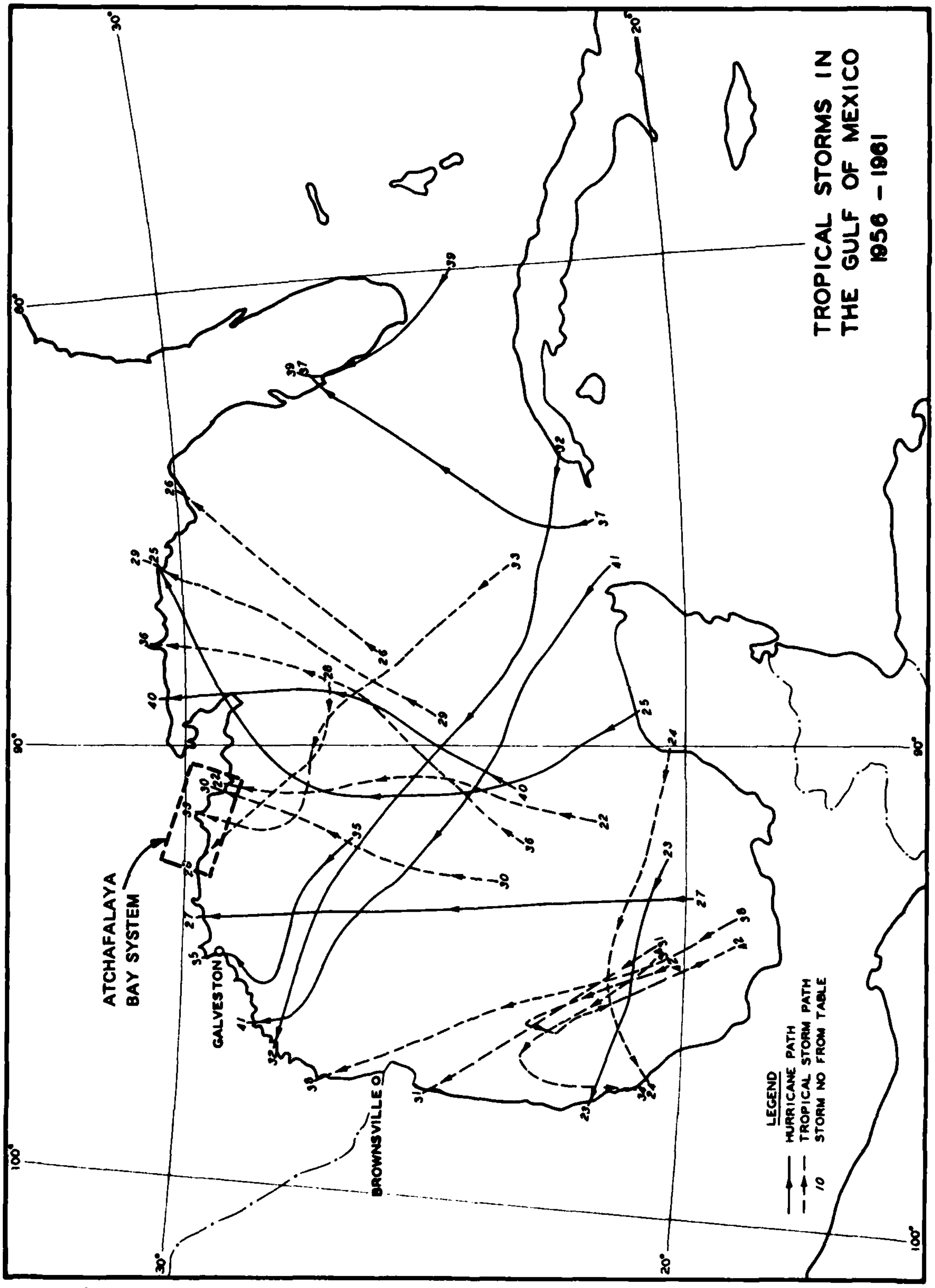
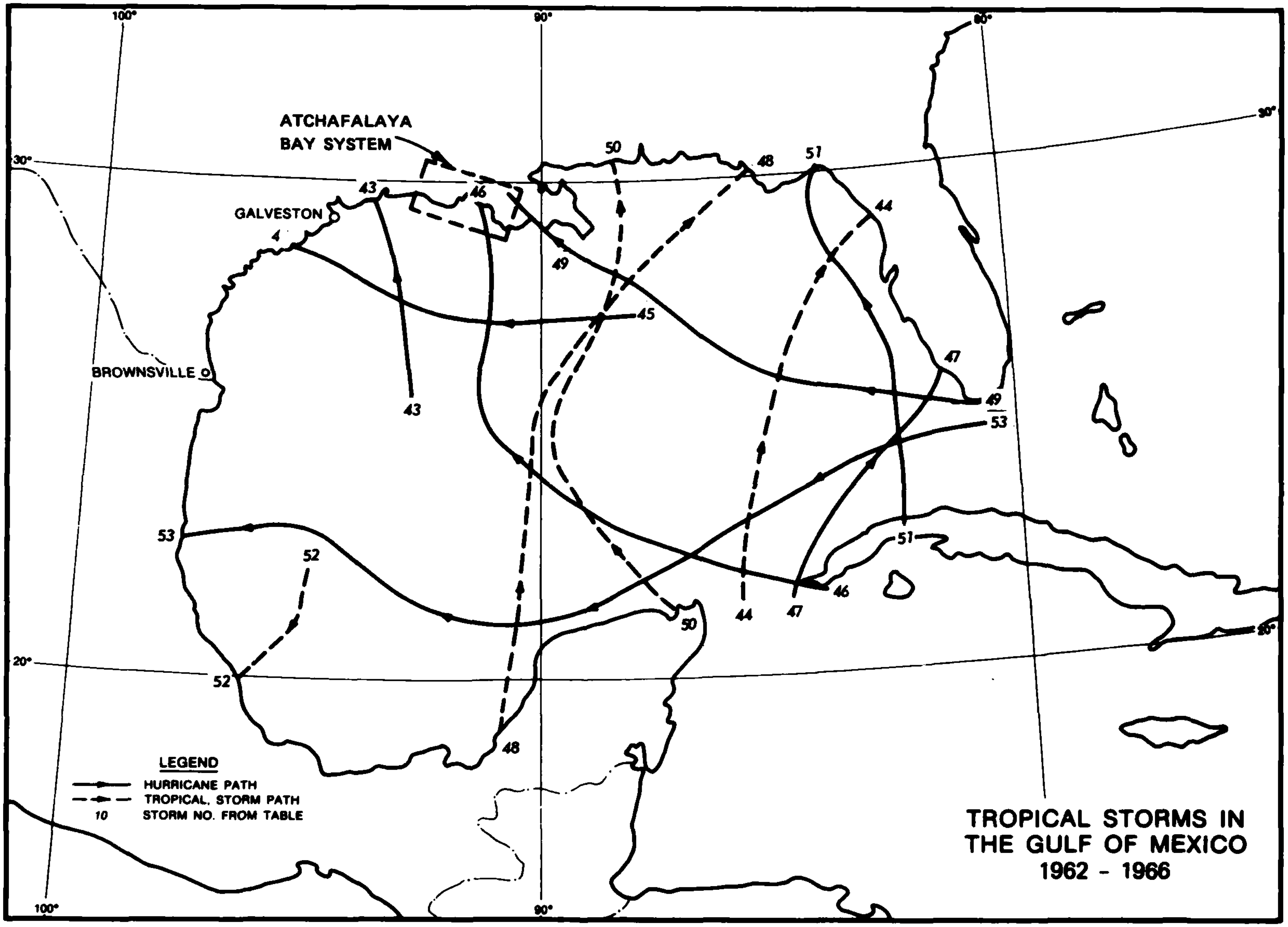

TROPICAL STORMS IN
THE GULF OF MEXICO
1956 - 1961
ATCHAFALAYA
BAY SYSTEM
GALVESTON
BROWNSVILLE
LEGEND
HURRICANE PATH
TROPICAL STORM PATH
10 STORM NO FROM TABLE

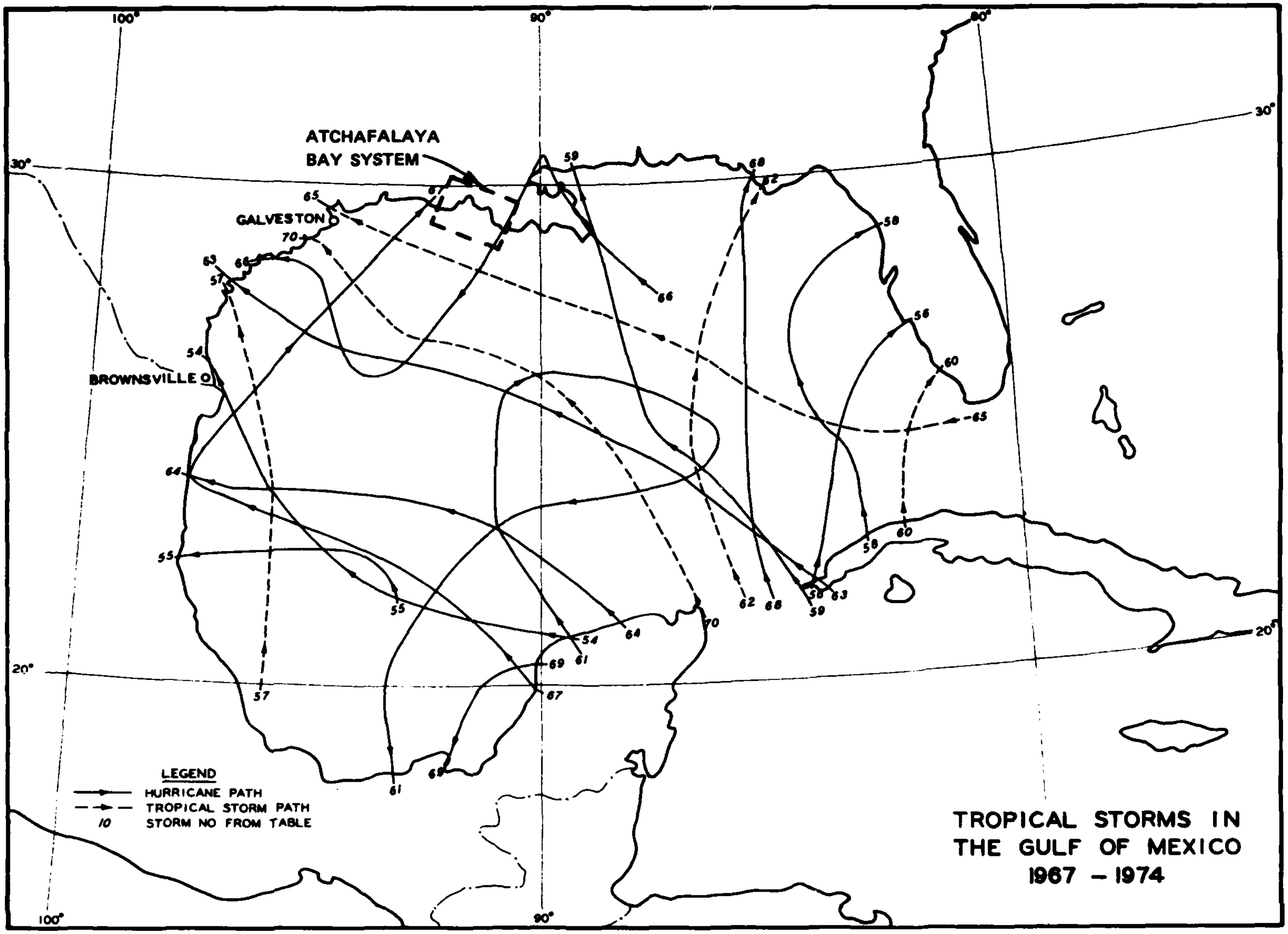
PLATE 2



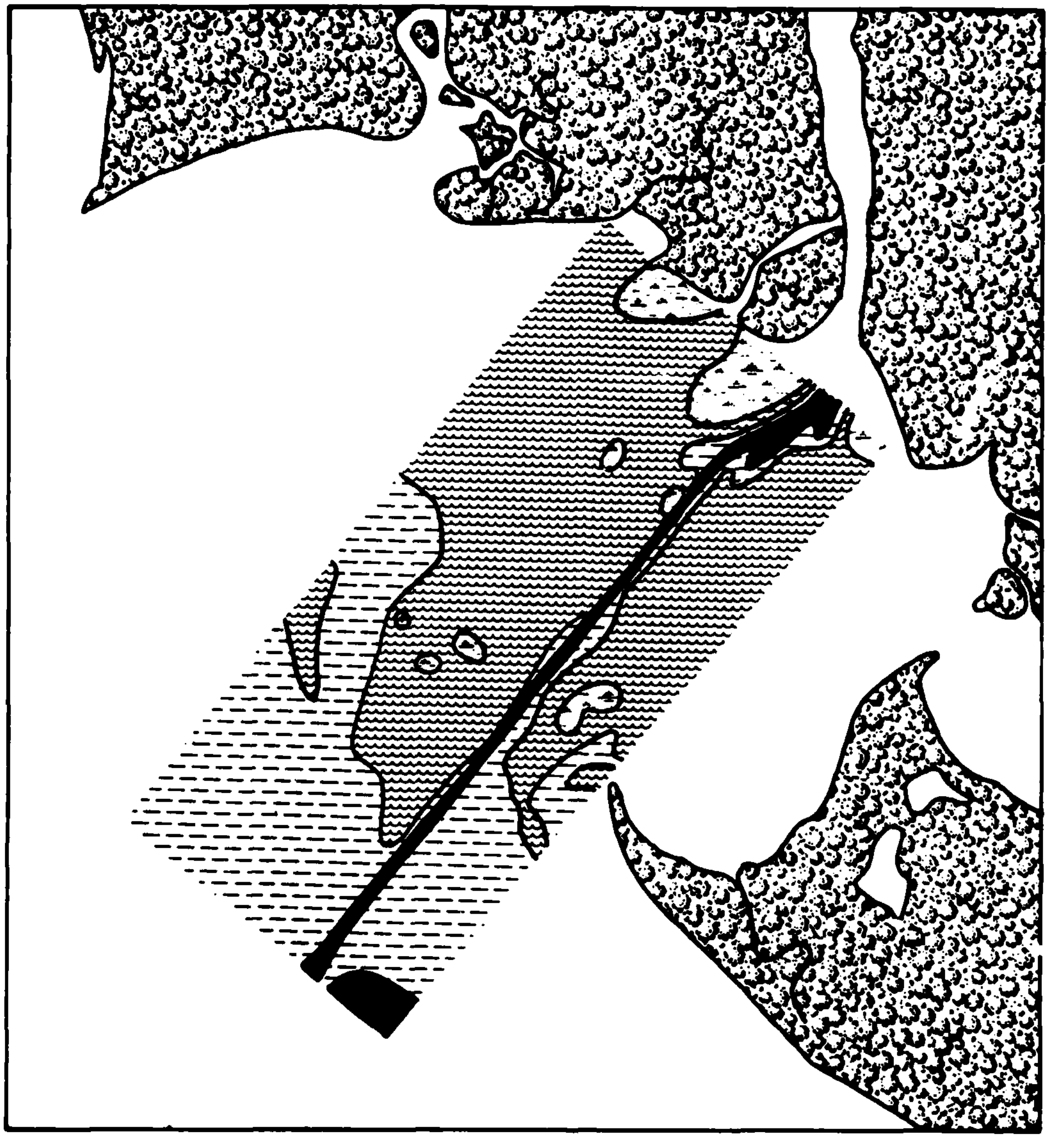
TROPICAL STORMS IN
THE GULF OF MEXICO
1962 - 1966

PLATE 3

PLATE 4



TROPICAL STORMS IN
THE GULF OF MEXICO
1967 – 1974
ATCHAFALAYA
BAY SYSTEM
GALVESTON
BROWNSVILLE
LEGEND
HURRICANE PATH
TROPICAL STORM PATH
10 STORM NO FROM TABLE
100°
90°
80°
30°
20°

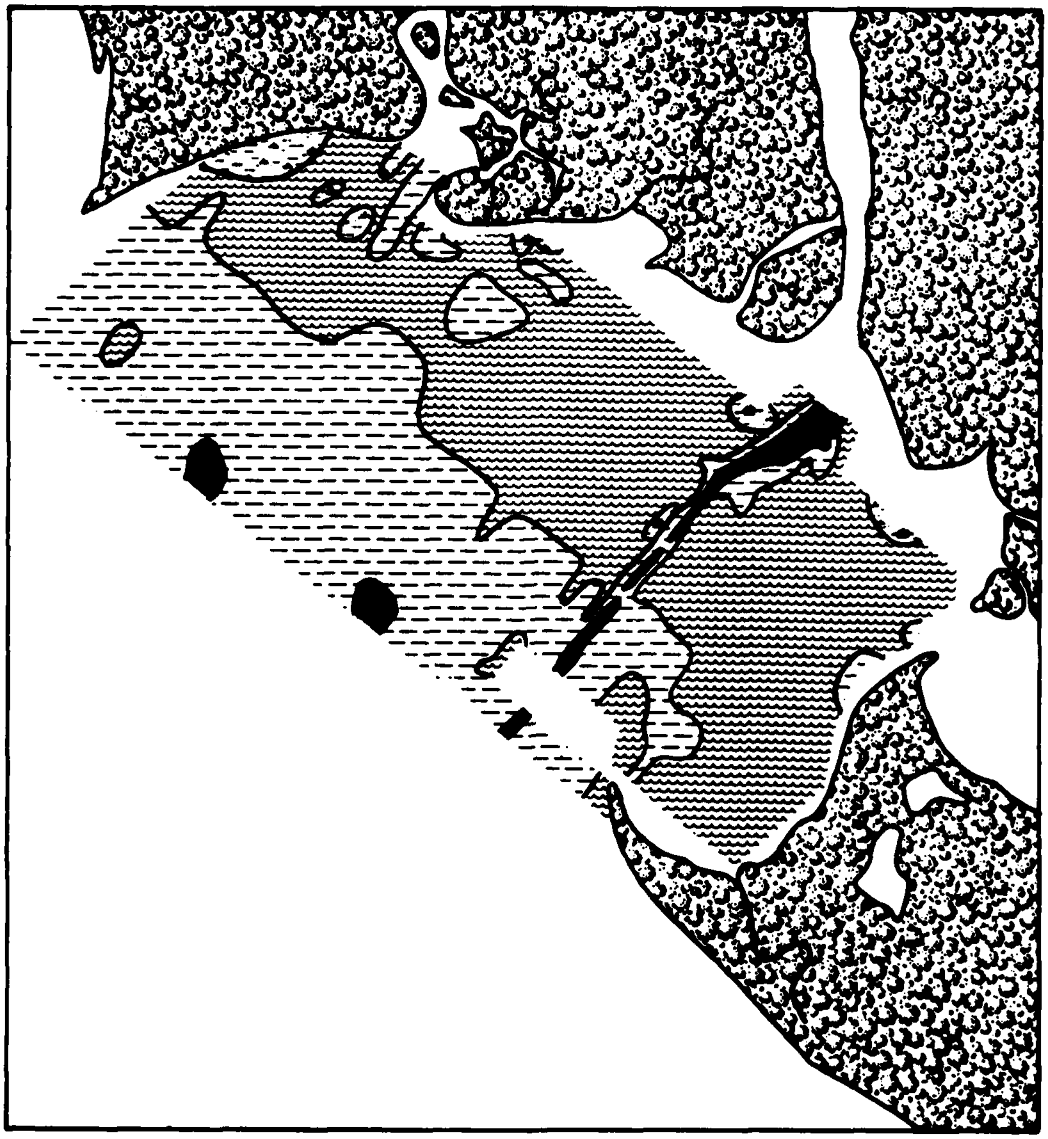


LEGEND

- GREATER THAN NGVD IN 1962
- NGVD TO -3 FT
- -3 TO -6 FT
- -6 TO -9 FT
- LESS THAN -9 FT

**PROTOTYPE
BATHYMETRIC CONDITION
1961**

PLATE 5



LEGEND

GREATER THAN NGVD IN 1962

NGVD TO -3 FT

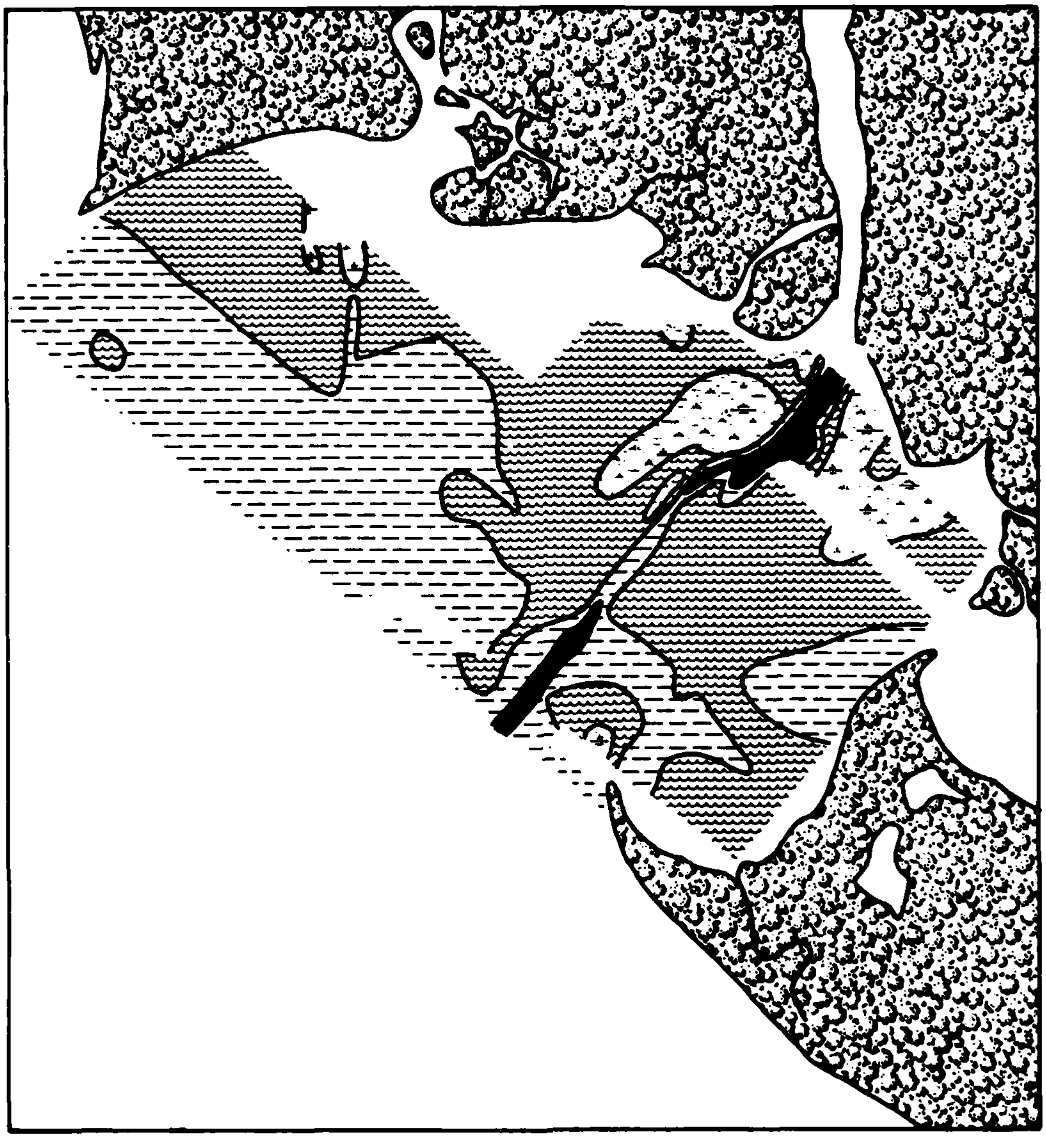
-3 TO -6 FT

-6 TO -9 FT

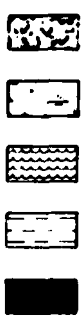
LESS THAN -9 FT

PROTOTYPE
BATHYMETRIC CONDITION
1967

PLATE 6



LEGEND



GREATER THAN NGVD IN 1962

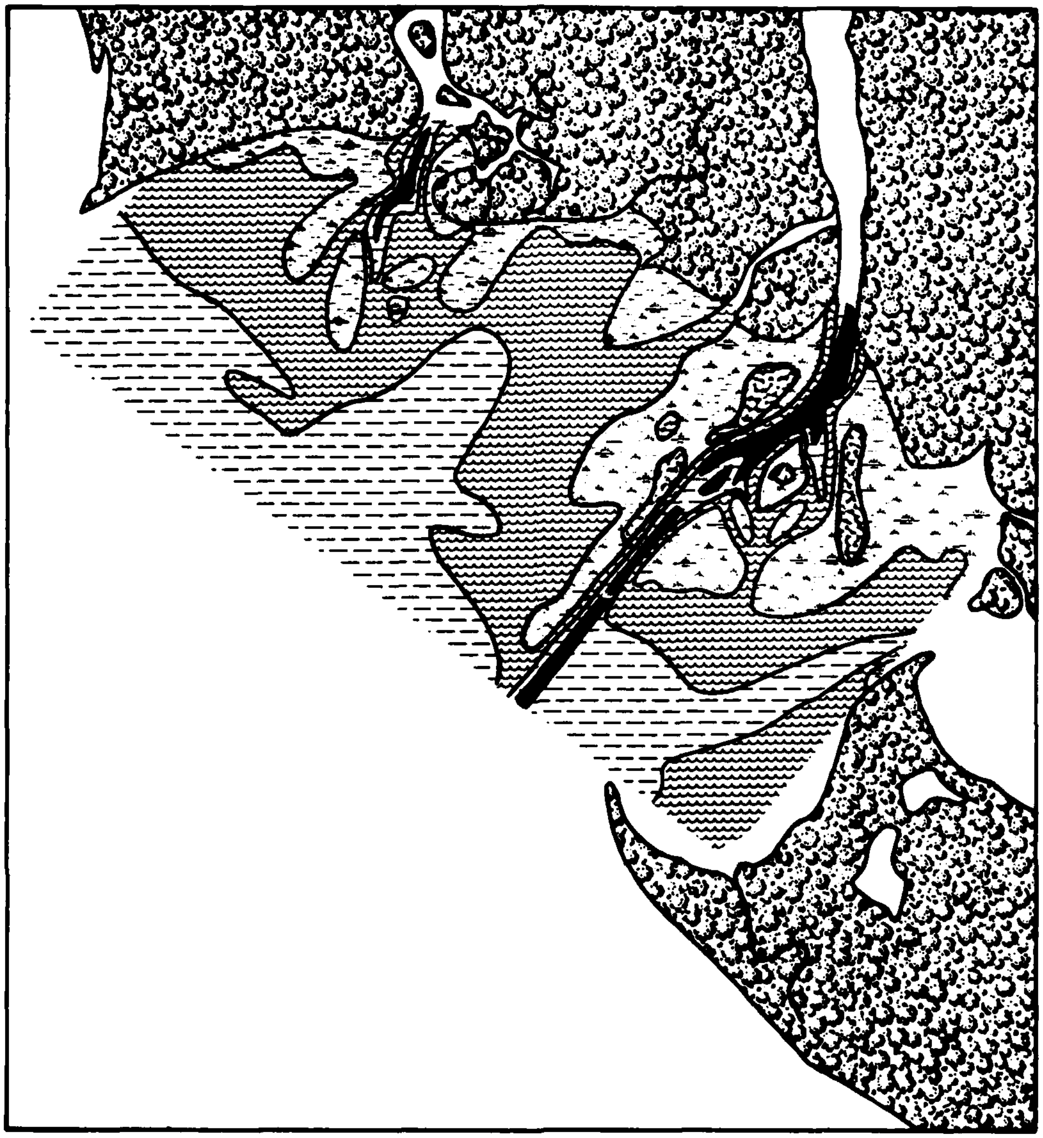
NGVD TO -3 FT

-3 TO -6 FT

-6 TO -9 FT

LESS THAN -9 FT

PROTOTYPE
BATHYMETRIC CONDITION
1972



LEGEND

GREATER THAN NGVD IN 1962

NGVD TO -3 FT

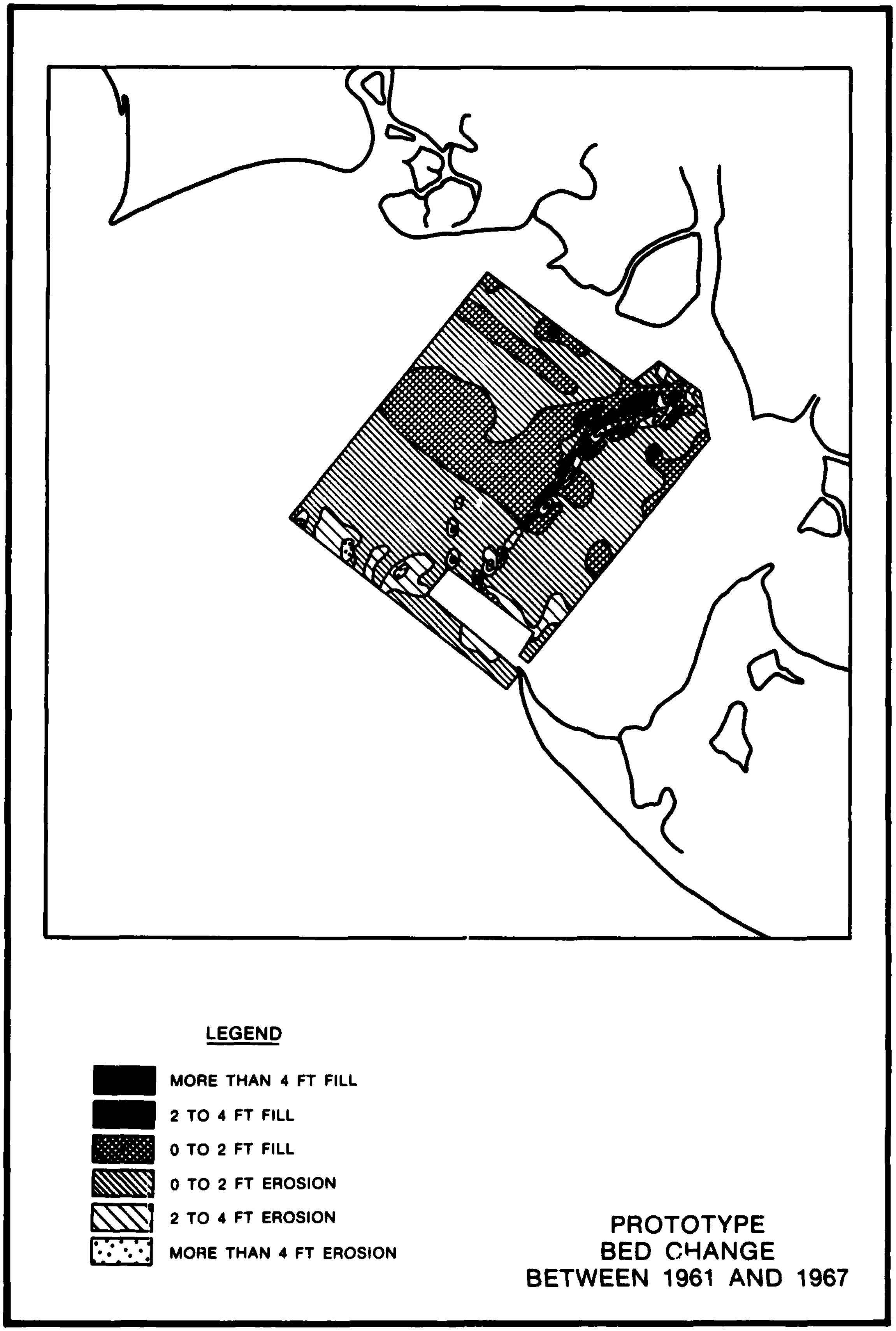
-3 TO -6 FT

-6 TO -9 FT

LESS THAN -9 FT

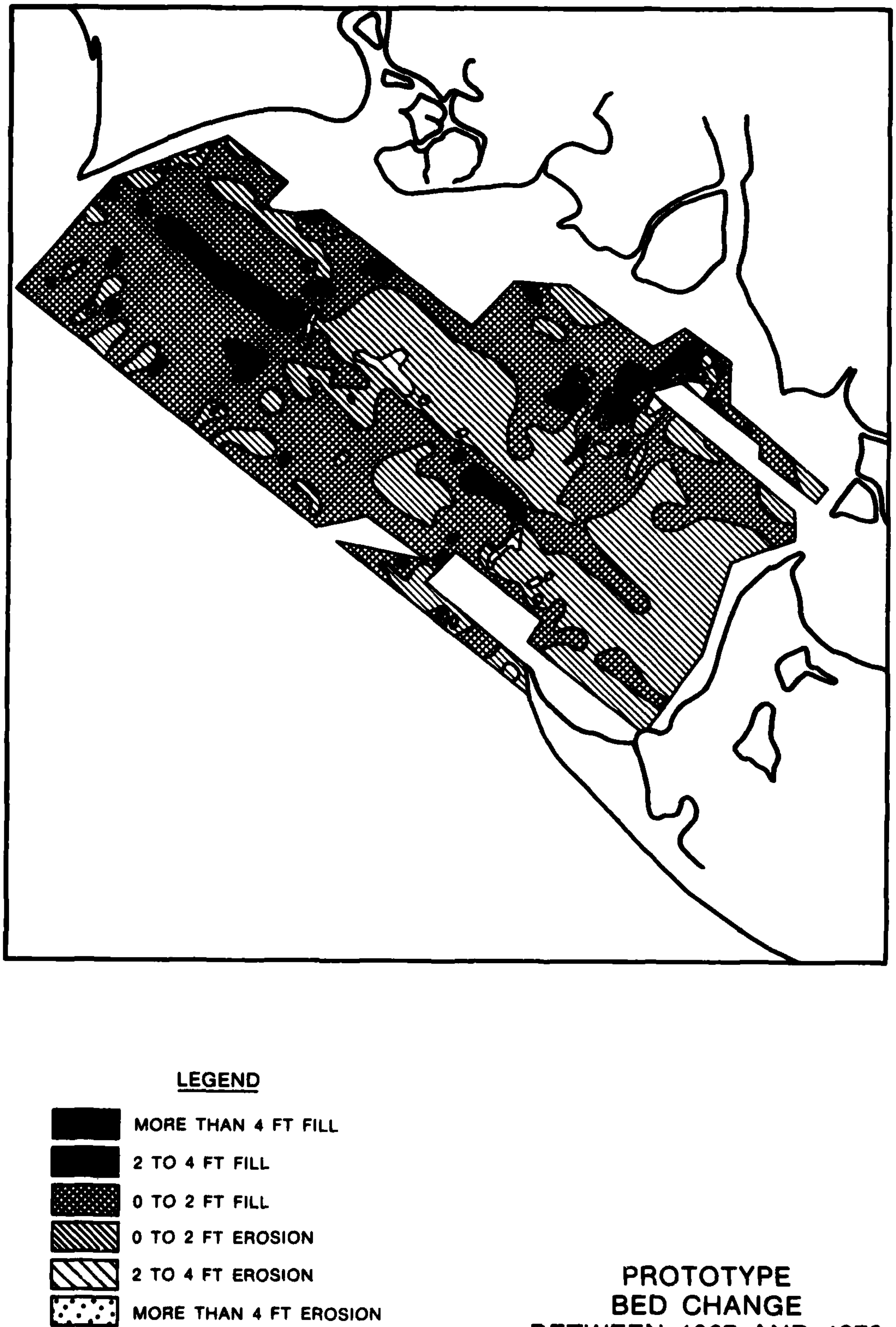
**PROTOTYPE
BATHYMETRIC CONDITION
1977**

PLATE 8



PROTOTYPE
BED CHANGE
BETWEEN 1961 AND 1967

PLATE 9



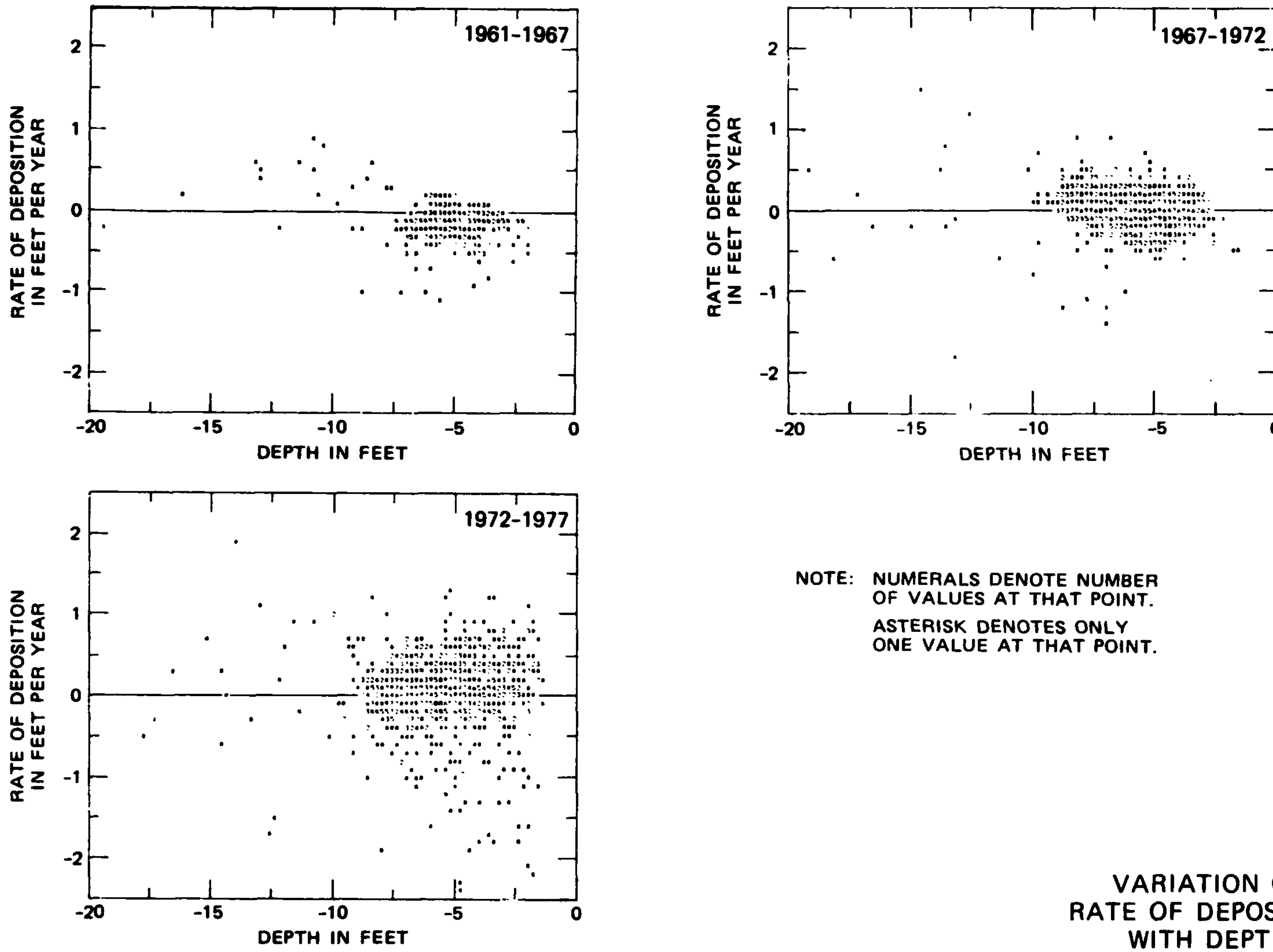
PROTOTYPE
BED CHANGE
BETWEEN 1967 AND 1972

PLATE 10

LEGEND

- MORE THAN 4 FT FILL
- 2 TO 4 FT FILL
- 0 TO 2 FT FILL
- 0 TO 2 FT EROSION
- 2 TO 4 FT EROSION
- MORE THAN 4 FT EROSION

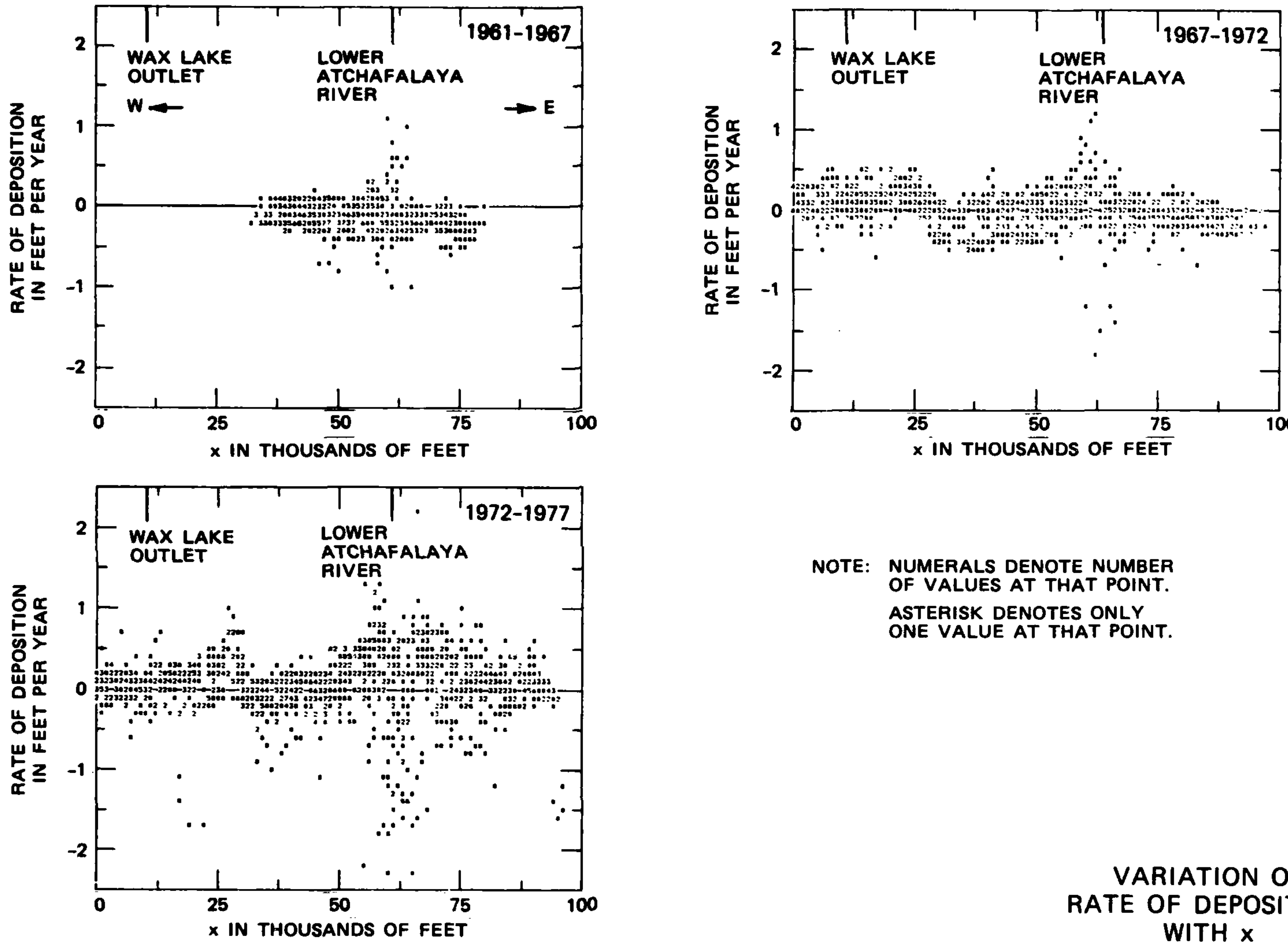
PROTOTYPE
BED CHANGE
BETWEEN 1972 AND 1977



NOTE: NUMERALS DENOTE NUMBER OF VALUES AT THAT POINT.
ASTERISK DENOTES ONLY ONE VALUE AT THAT POINT.

VARIATION OF
RATE OF DEPOSITION
WITH DEPTH

PLATE 12

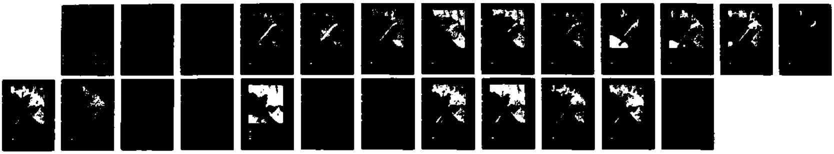


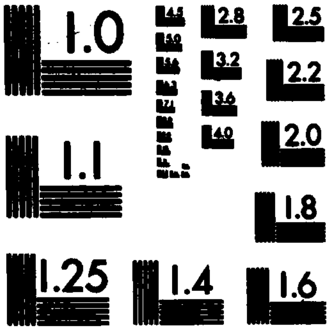
NOTE: NUMERALS DENOTE NUMBER OF VALUES AT THAT POINT.
ASTERISK DENOTES ONLY ONE VALUE AT THAT POINT.

VARIATION OF
RATE OF DEPOSITION
WITH x

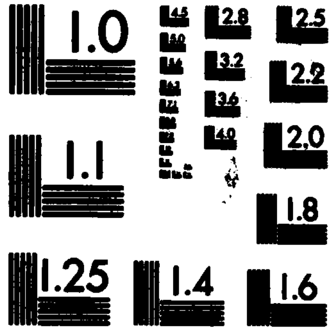
AD-A120 778 THE ATCHAFALAYA RIVER DELTA REPORT 3 EXTRAPOLATION OF DELTA GROWTH(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. J V LETTER ET AL. JUL 82 2/2

UNCLASSIFIED WES/TR/HL-82-15-3 F/G 8/8 NL

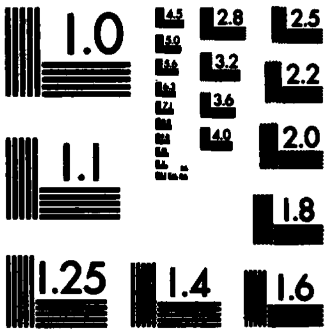




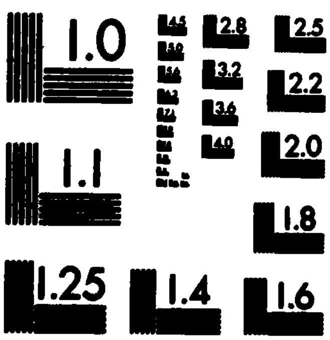
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



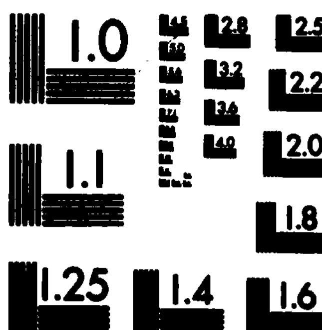
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

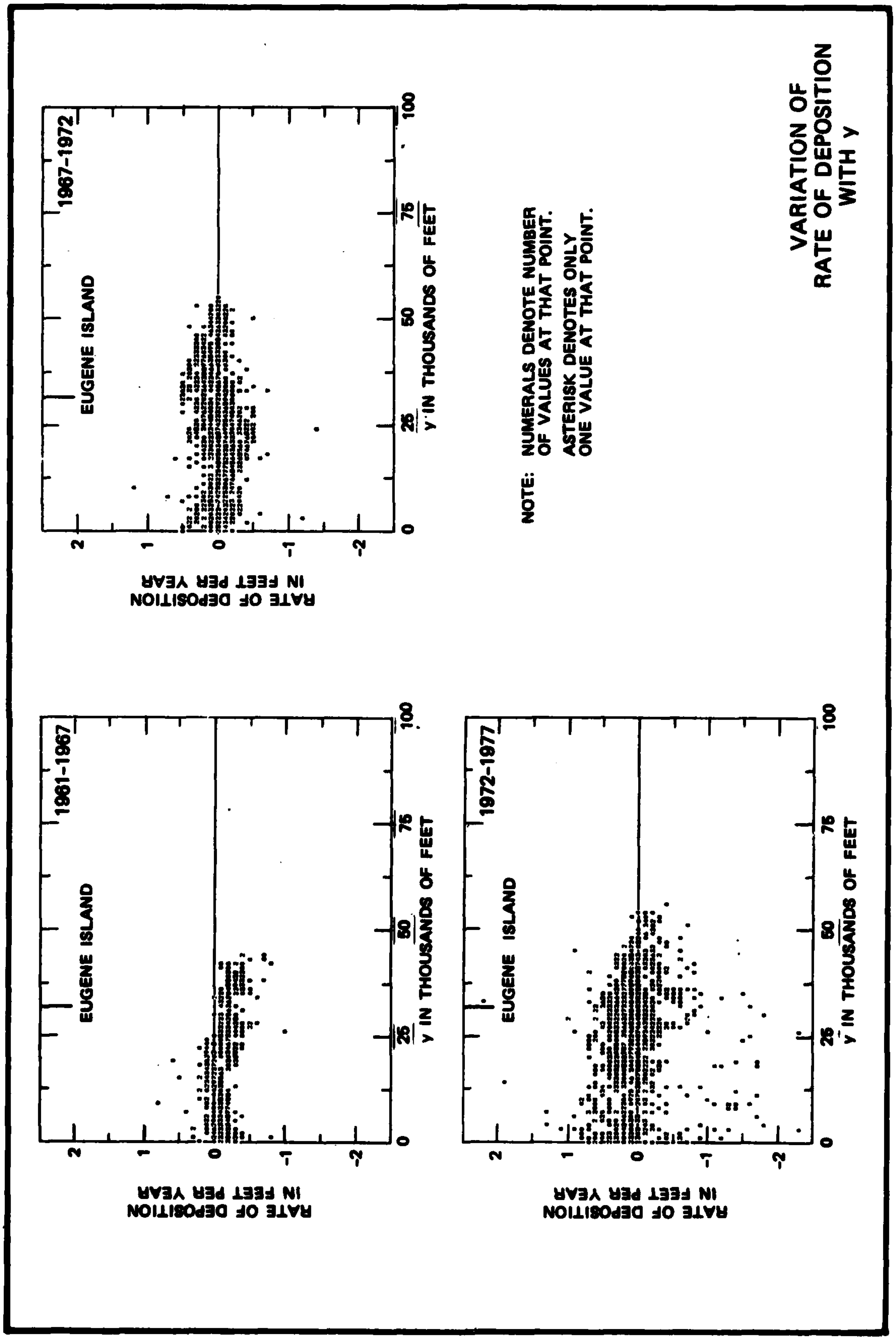
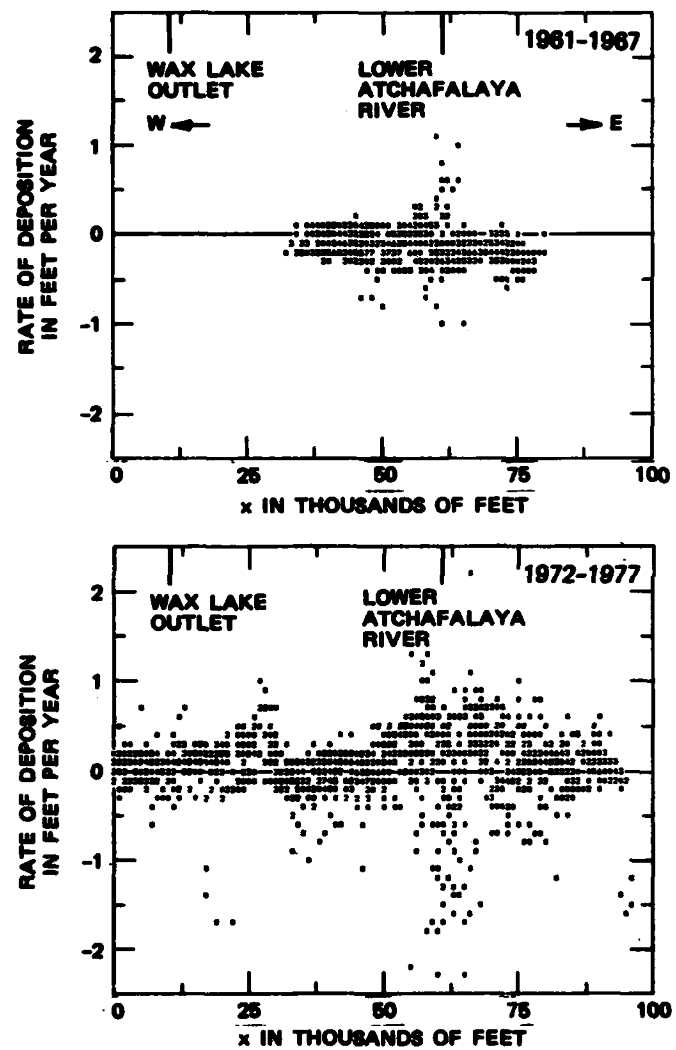

VARIATION OF
RATE OF DEPOSITION
WITH Y
NOTE: NUMERALS DENOTE NUMBER
OF VALUES AT THAT POINT.
ASTERISK DENOTES ONLY
ONE VALUE AT THAT POINT.
EUGENE ISLAND
1967-1972
EUGENE ISLAND
1961-1967
EUGENE ISLAND
1972-1977
RATE OF DEPOSITION
IN FEET PER YEAR
Y IN THOUSANDS OF FEET
2
1
0
-1
-2
0
25
50
75
100

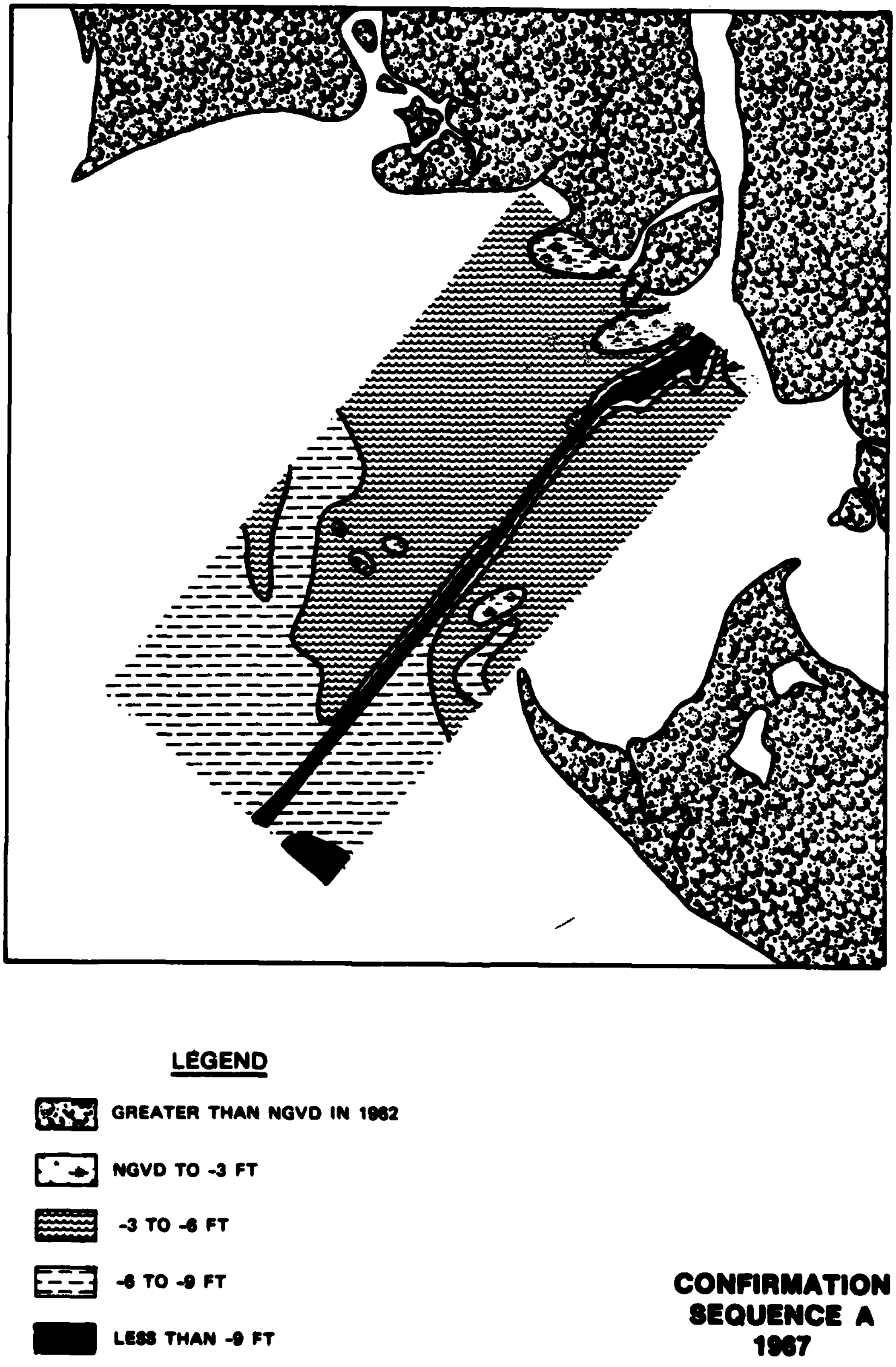
PLATE 14



NOTE: NUMERALS DENOTE NUMBER OF VALUES AT THAT POINT.
ASTERISK DENOTES ONLY ONE VALUE AT THAT POINT.

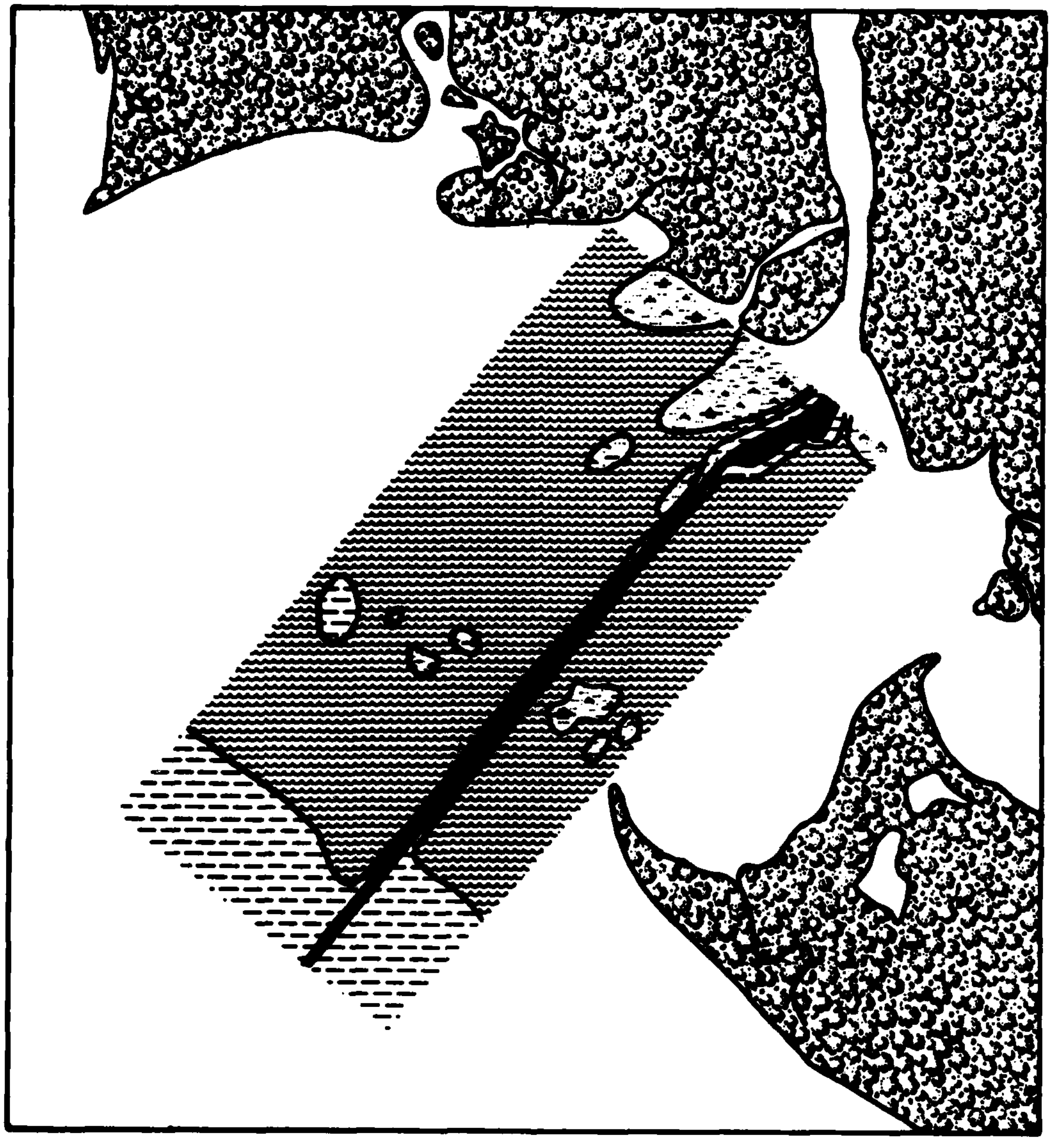
VARIATION OF
RATE OF DEPOSITION
WITH x

PLATE 13



CONFIRMATION
SEQUENCE A
1967

PLATE 15

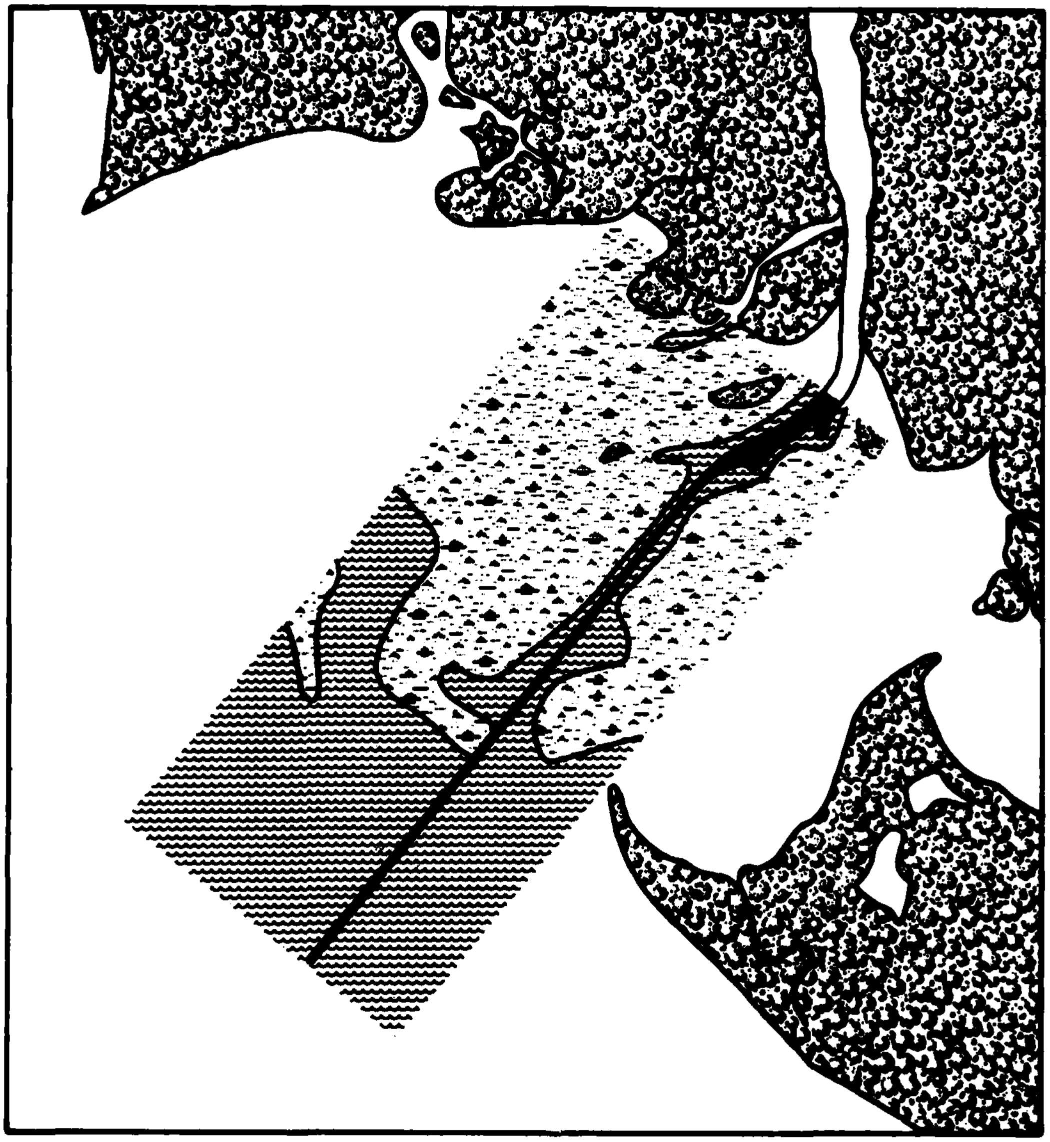


LEGEND

- GREATER THAN NGVD IN 1962
- NGVD TO -3 FT
- -3 TO -6 FT
- -6 TO -9 FT
- LESS THAN -9 FT

CONFIRMATION SEQUENCE A 1972

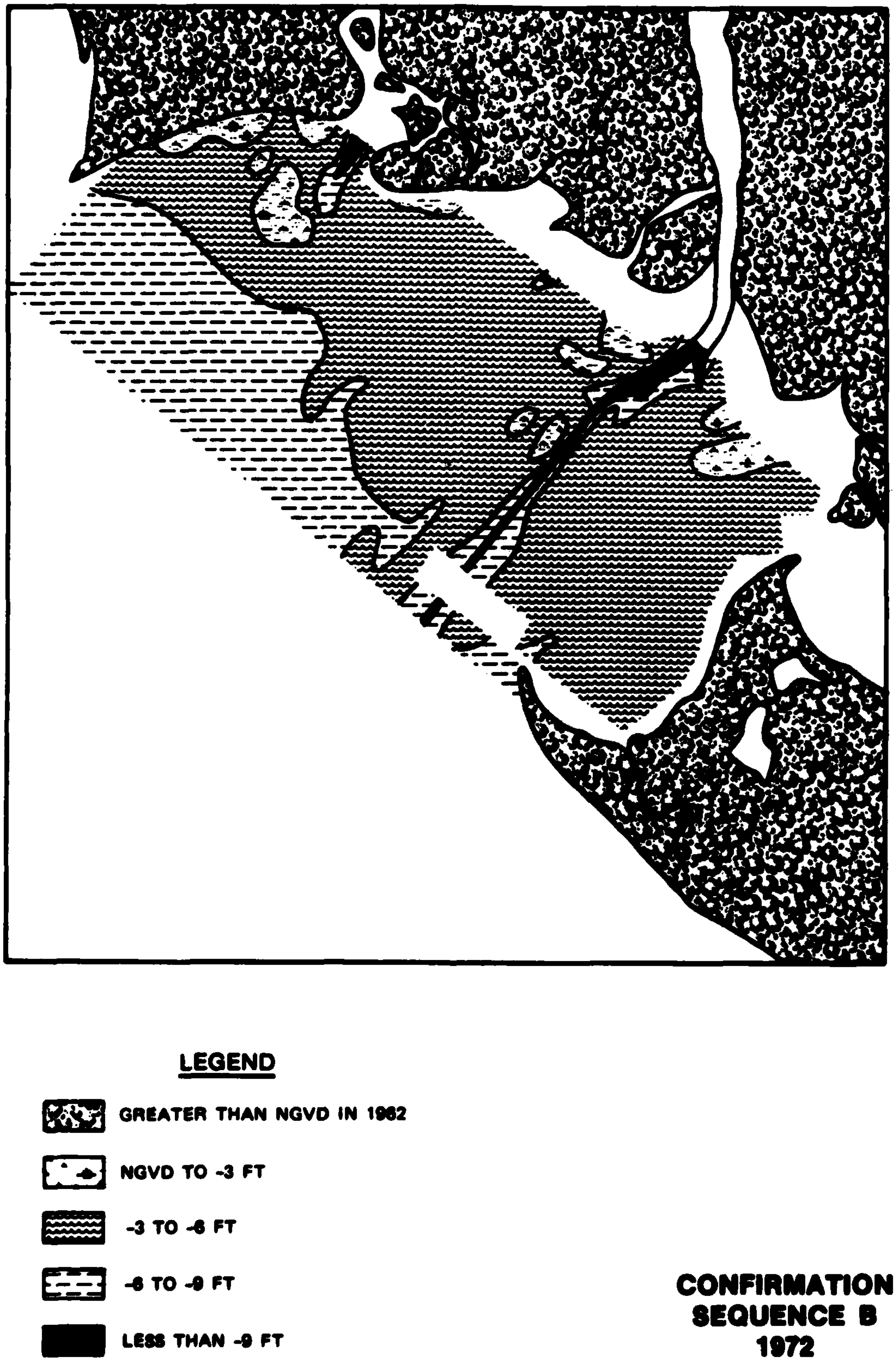
PLATE 16



LEGEND

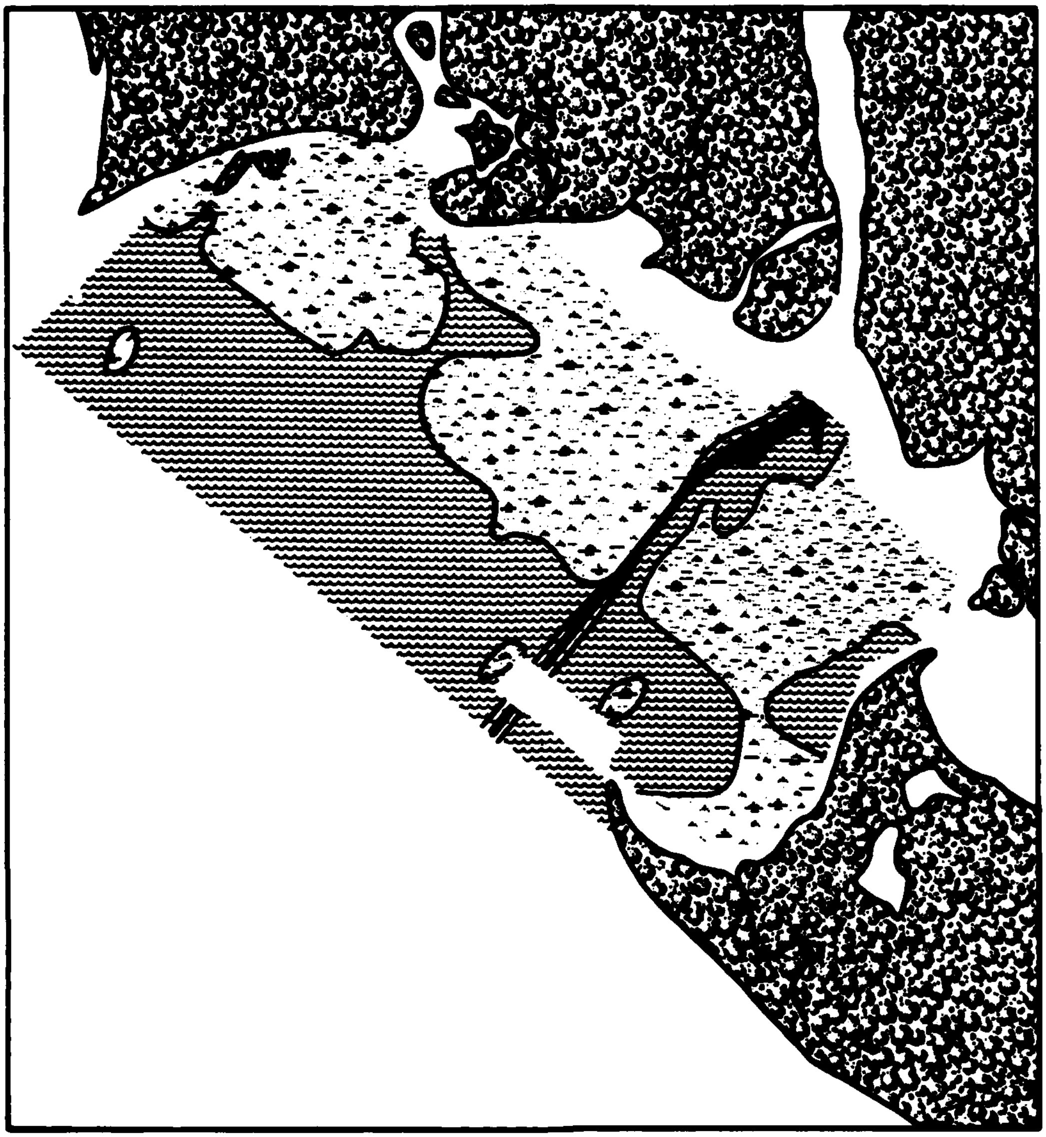
	GREATER THAN NGVD IN 1962
	GREATER THAN NGVD
	NGVD TO -3 FT
	-3 TO -6 FT
	LESS THAN -9 FT

CONFIRMATION SEQUENCE A 1977



CONFIRMATION
SEQUENCE B
1972

PLATE 18



LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- -6 TO -9 FT
- LESS THAN -9 FT

CONFIRMATION SEQUENCE B 1977

LEGEND

GREATER THAN NGVD IN 1962

GREATER THAN NGVD

NGVD TO -3 FT

-3 TO -6 FT

-6 TO -9 FT

LESS THAN -9 FT

CONFIRMATION SEQUENCE C 1977

PLATE 20

LEGEND

GREATER THAN NGVD IN 1962

GREATER THAN NGVD

NGVD TO -3 FT

-3 TO -6 FT

-6 TO -9 FT

LESS THAN -9 FT

BASE YEAR
FOR EXTRAPOLATION
1977

PLATE 21

LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- -6 TO -9 FT
- LESS THAN -9 FT

BATHYMETRIC CONDITION
YEAR 10
EXTRAPOLATION

LEGEND

GREATER THAN NGVD IN 1962

GREATER THAN NGVD

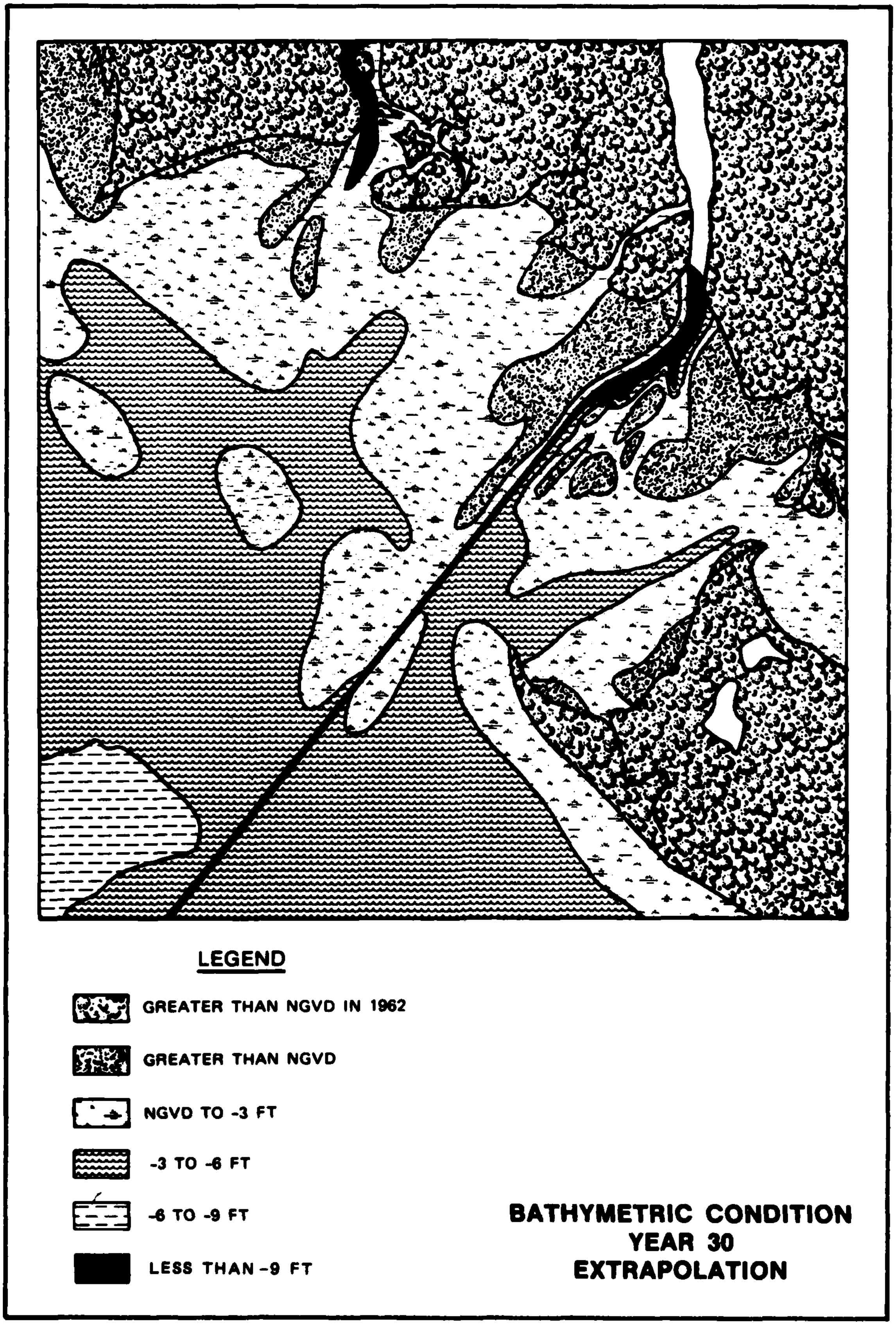
NGVD TO -3 FT

-3 TO -6 FT

-6 TO -9 FT

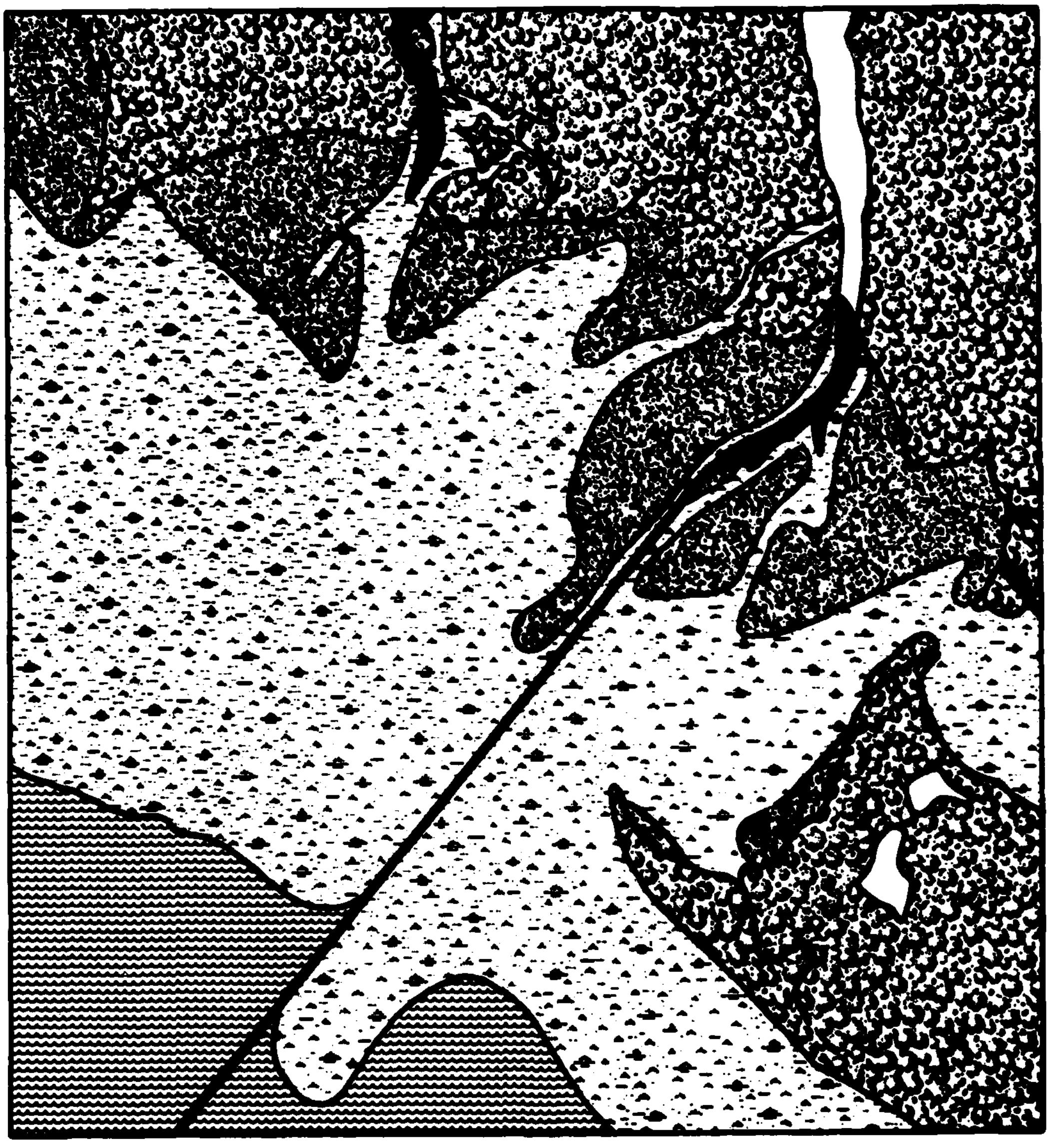
LESS THAN -9 FT

BATHYMETRIC CONDITION
YEAR 20
EXTRAPOLATION



LEGEND
GREATER THAN NGVD IN 1962
GREATER THAN NGVD
NGVD TO -3 FT
-3 TO -6 FT
-6 TO -9 FT
LESS THAN -9 FT
BATHYMETRIC CONDITION
YEAR 30
EXTRAPOLATION

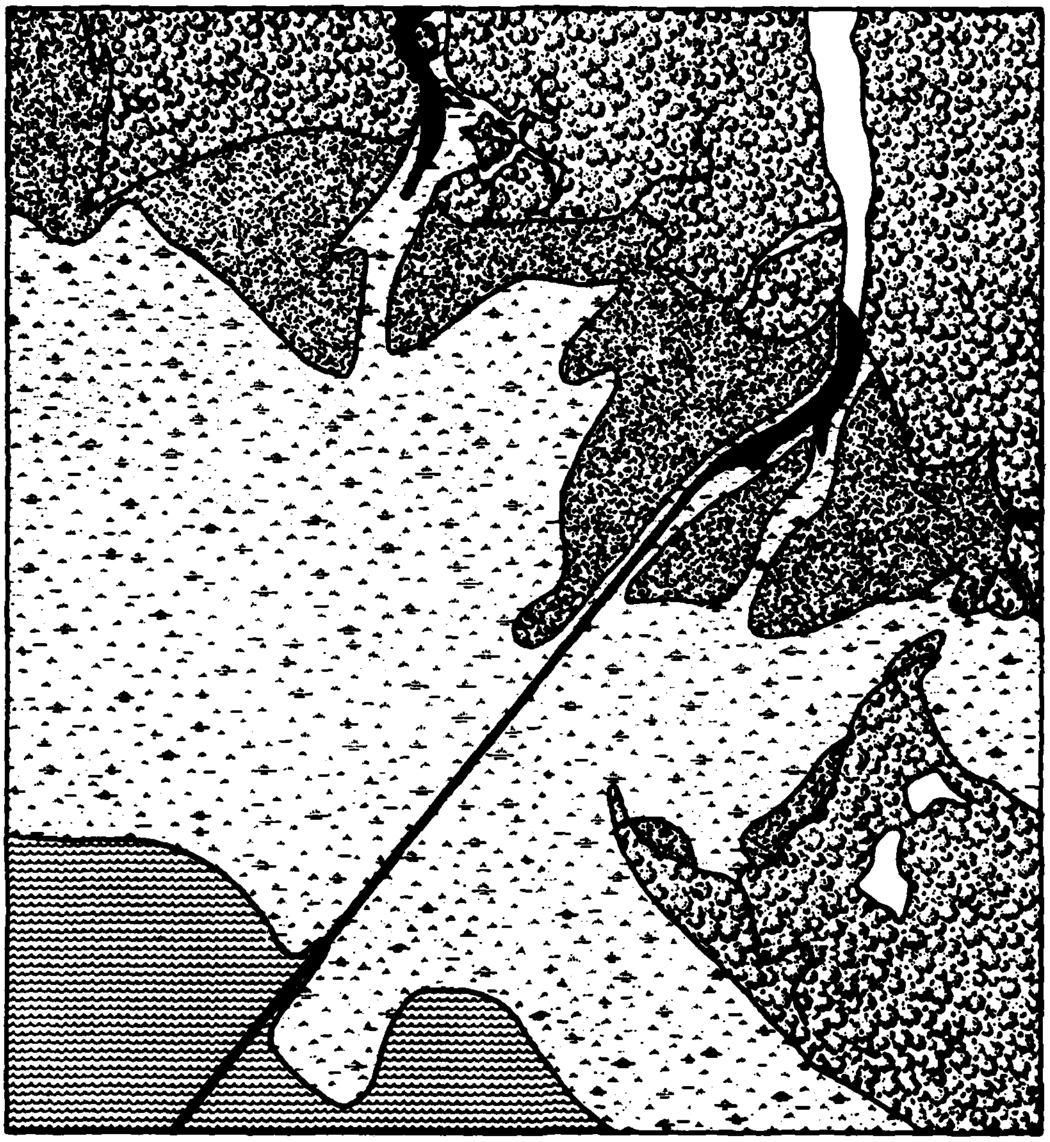
PLATE 24



LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- LESS THAN -9 FT

BATHYMETRIC CONDITION
YEAR 40
EXTRAPOLATION

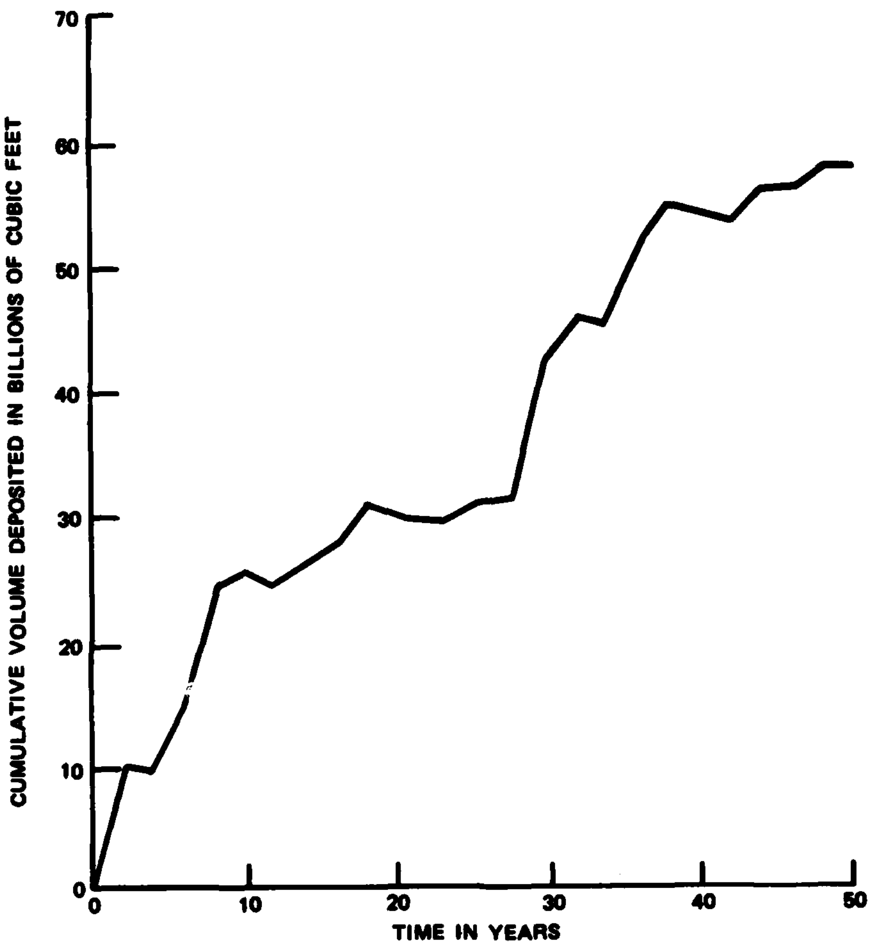


LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- -6 TO -9 FT
- LESS THAN -9 FT

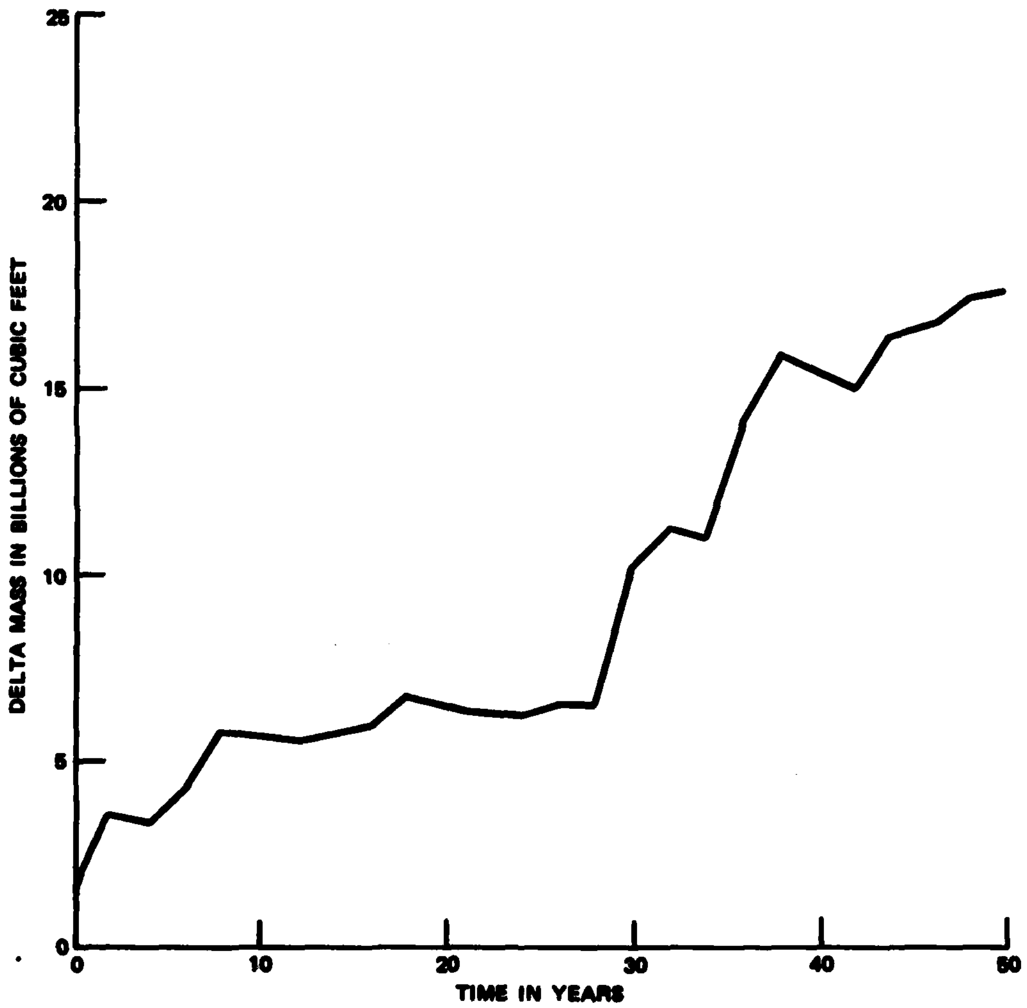
BATHYMETRIC CONDITION
YEAR 50
EXTRAPOLATION

PLATE 26



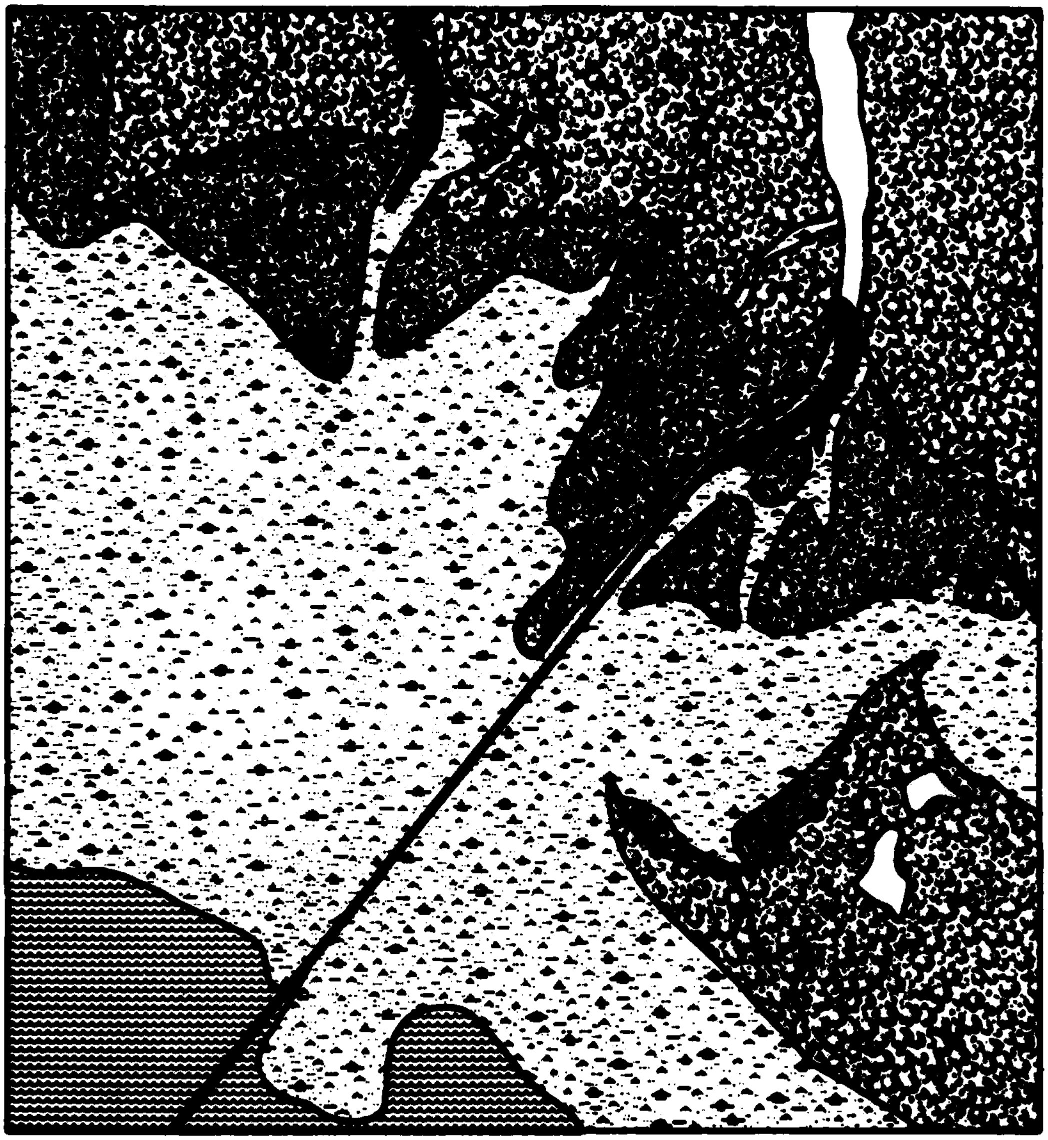
CUMULATIVE VOLUME
OF DEPOSITION

PLATE 27



EXTRAPOLATED
DELTA MASS

PLATE 28

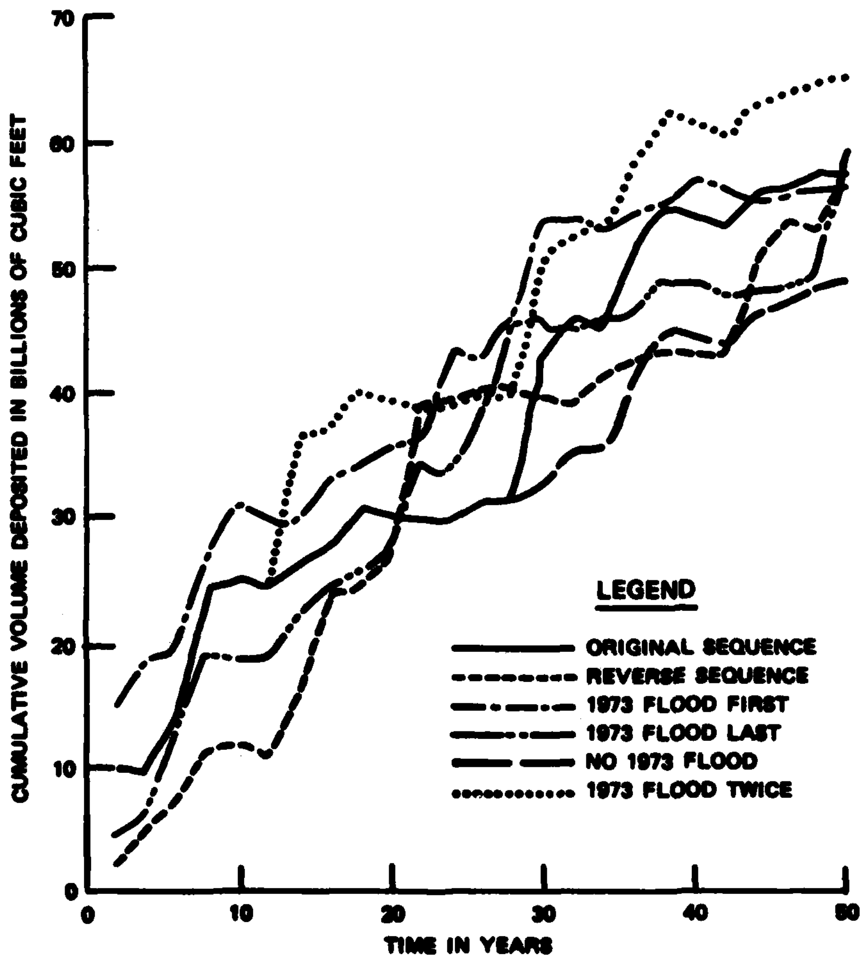


LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- LESS THAN -6 FT

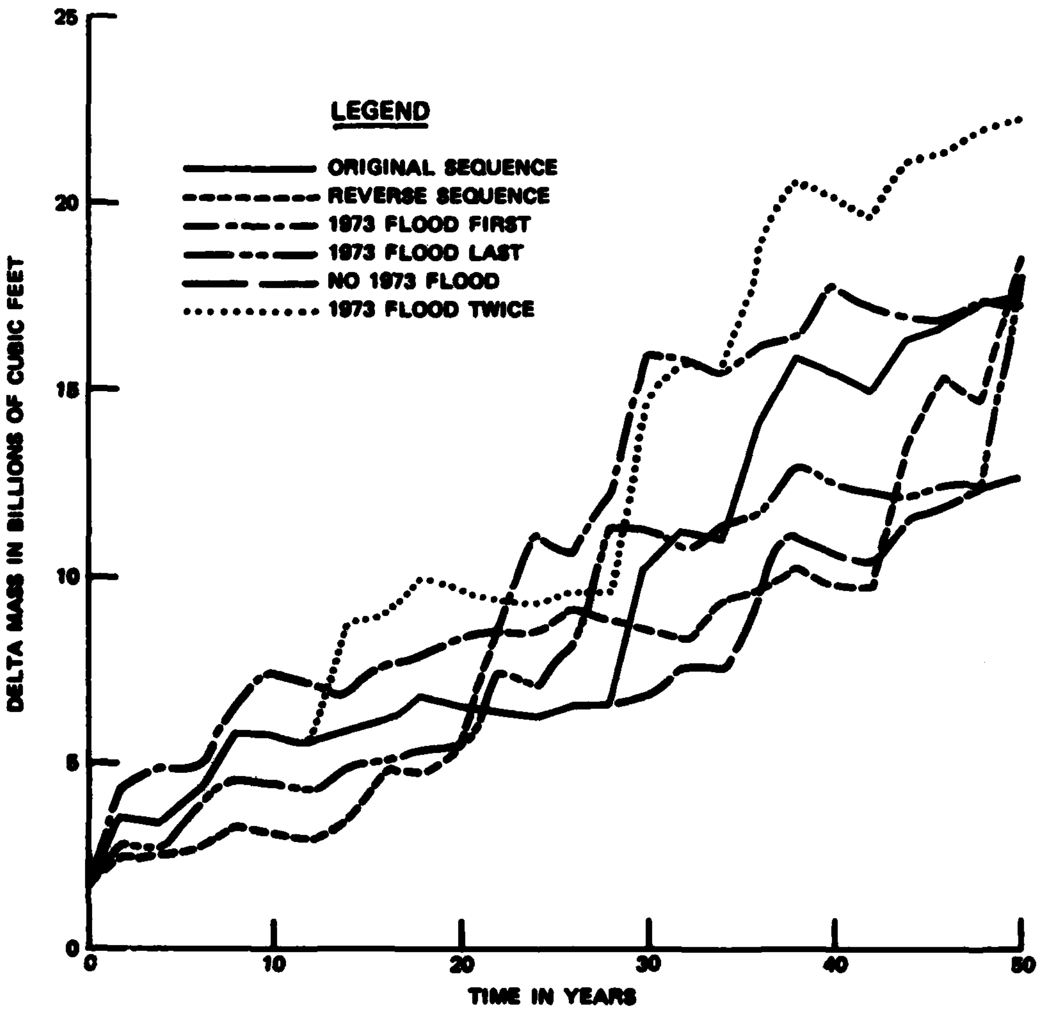
SENSITIVITY TEST
YEAR 50
REVERSE SEQUENCE

PLATE 29



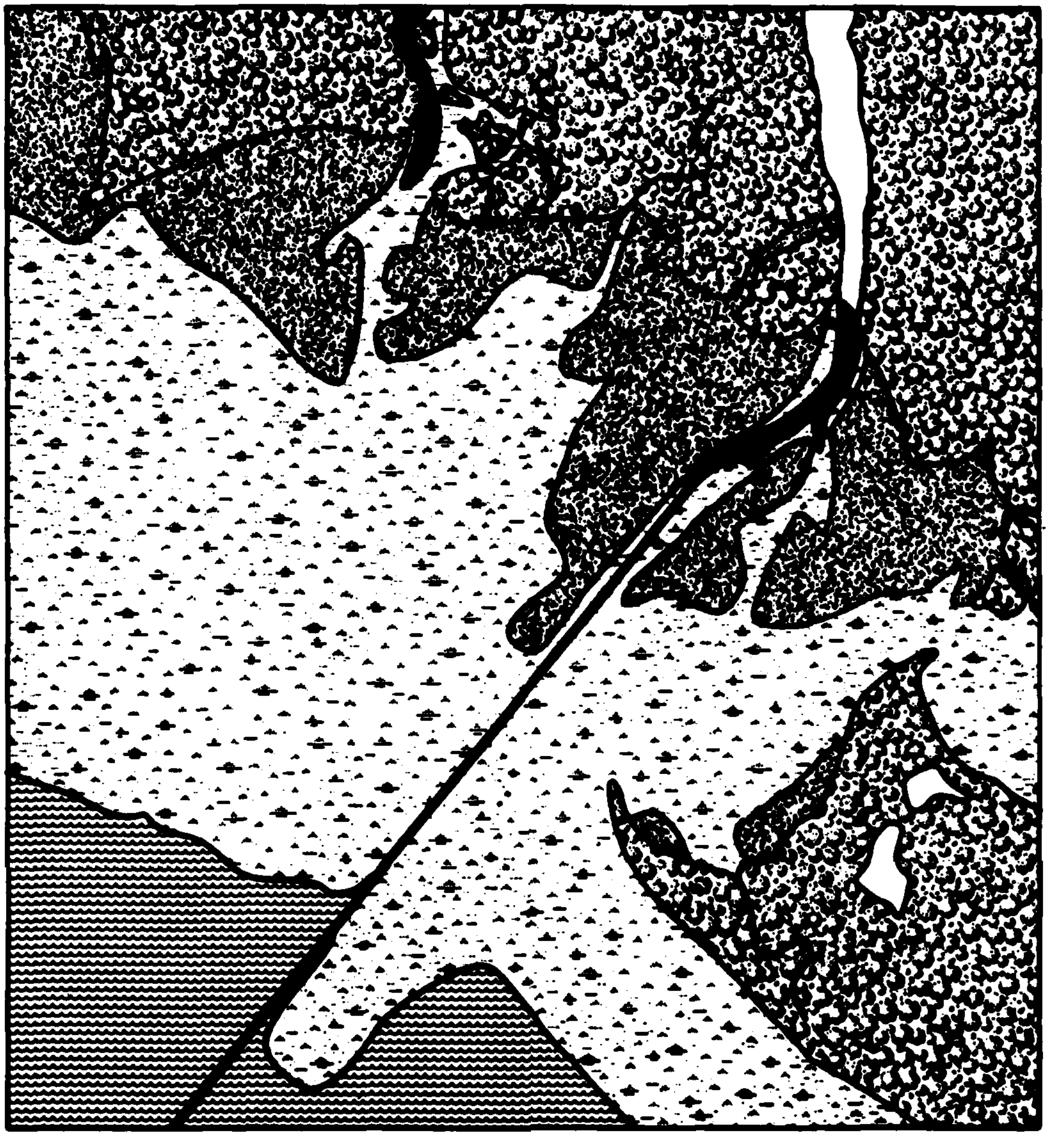
SENSITIVITY TESTS
CUMULATIVE VOLUME
OF DEPOSITION

PLATE 30



SENSITIVITY TESTS
DELTA MASS

PLATE 31



LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- LESS THAN -9 FT

SENSITIVITY TESTS
YEAR 50
1973 FLOOD
FIRST EVENT

PLATE 32

LEGEND

GREATER THAN NGVD IN 1982

GREATER THAN NGVD

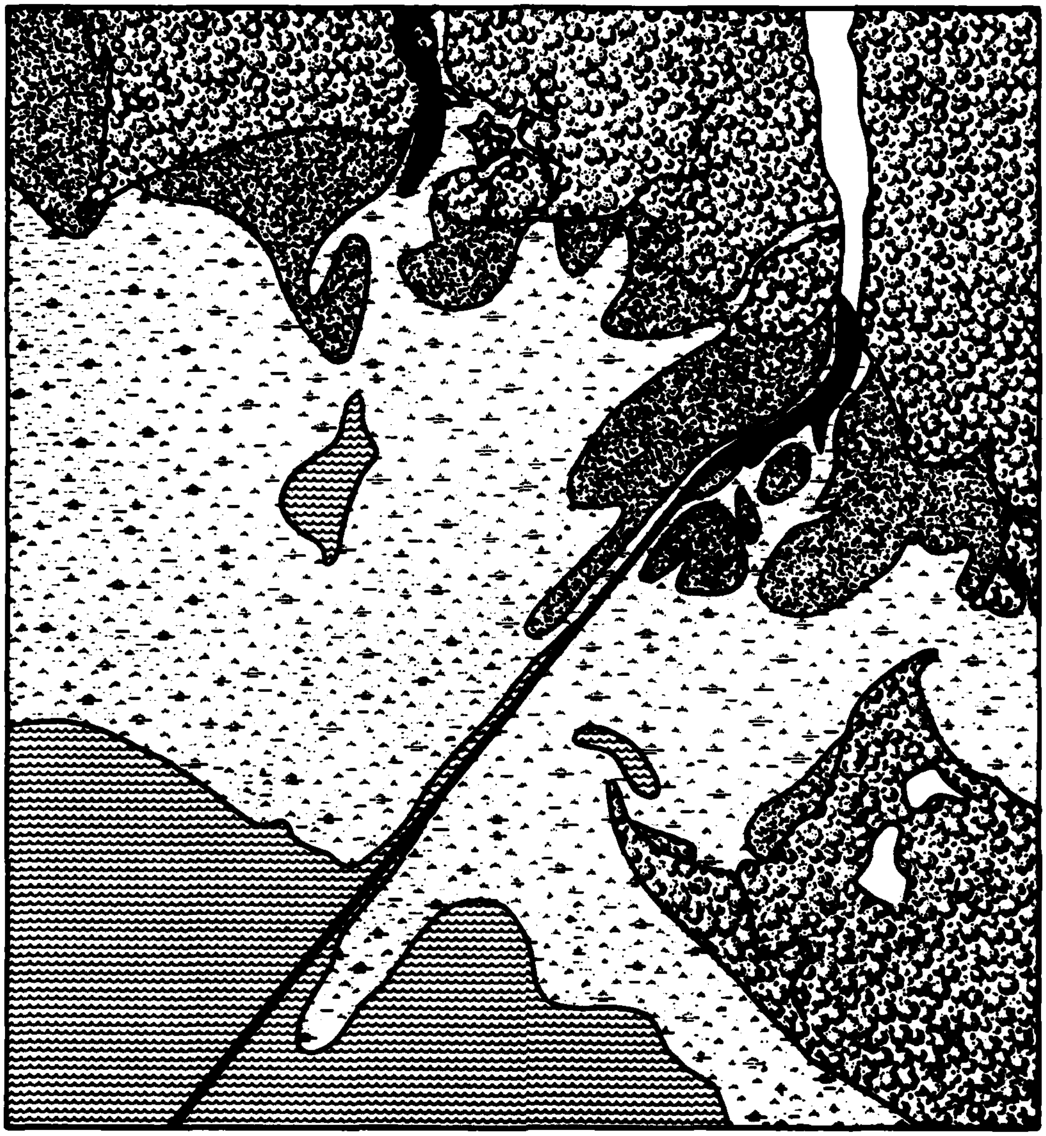
NGVD TO -3 FT

-3 TO -6 FT

LESS THAN -9 FT

SENSITIVITY TEST
YEAR 50
1973 FLOOD
LAST EVENT

PLATE 33



LEGEND

GREATER THAN NGVD IN 1962

GREATER THAN NGVD

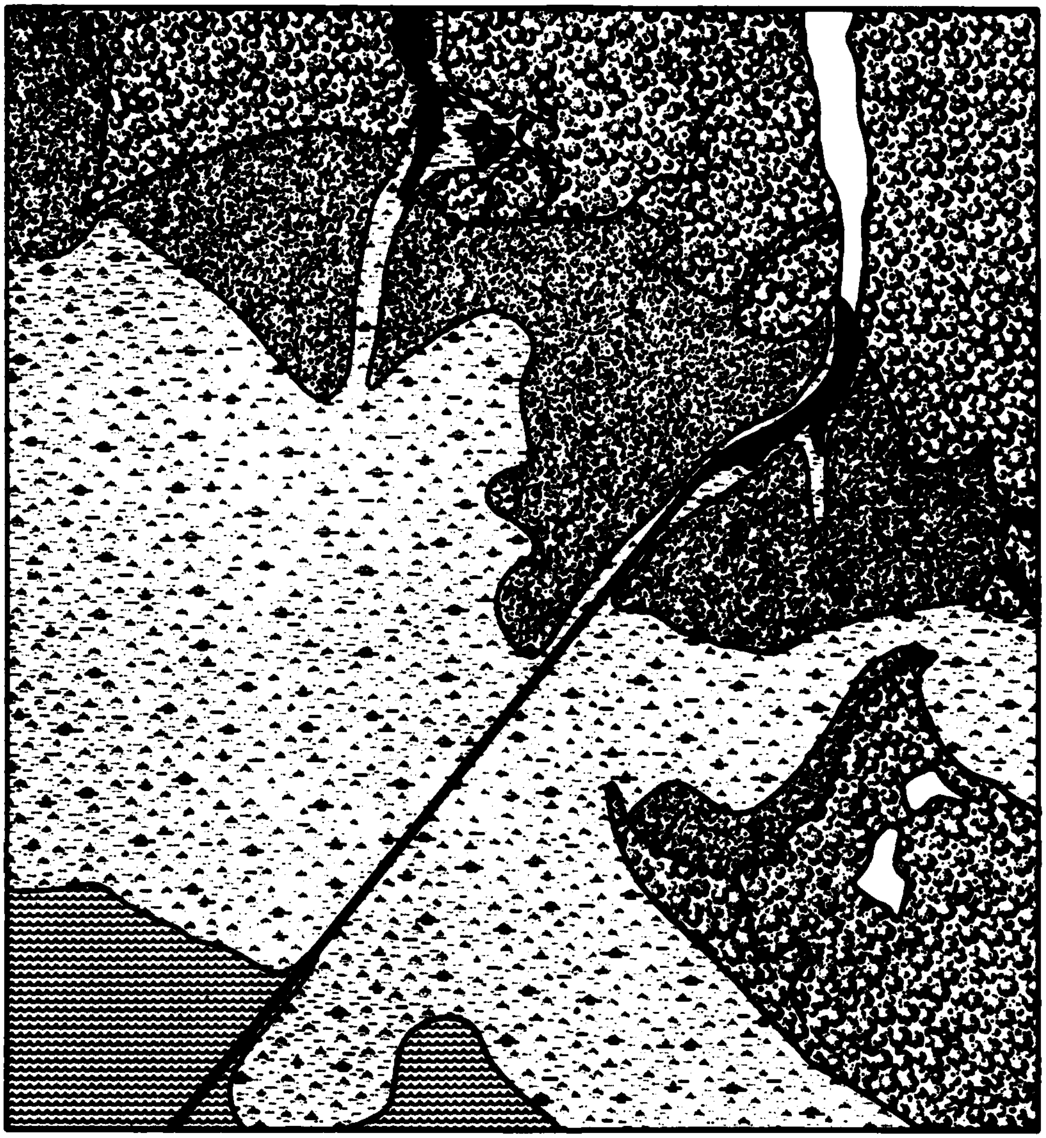
NGVD TO -3 FT

-3 TO -6 FT

LESS THAN -9 FT

SENSITIVITY TEST
YEAR 50
NO 1973 FLOOD

PLATE 34



LEGEND

- GREATER THAN NGVD IN 1962
- GREATER THAN NGVD
- NGVD TO -3 FT
- -3 TO -6 FT
- LESS THAN -9 FT

SENSITIVITY TEST
YEAR 50
1973 FLOOD
EVENT TWICE

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Letter, Joseph V.
The Atchafalaya River delta : Report 3 : extrapolation of delta growth / by Joseph V. Letter, Jr. (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.
68, [11] p., 35 p. of plates ; ill. ; 27 cm. -- (Technical report ; HL-82-15, Report 3)
Cover title.
"July 1982."
"Prepared for U.S. Army Engineer District, New Orleans."
Bibliography: p. 67-68.

1. Atchafalaya River (La.) 2. Deltas. 3. Hydrology--Research. 4. Regression analysis. 5. Sedimentation and deposition. I. United States. Army. Corps of Engineers. New Orleans District. II. U.S. Army Engineer Waterways Experiment Station. Hydraulics Laboratory. III. Title IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; HL-82-15, Report 3.
TA7.W34 no.HL-82-15 Report 3